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Improved Autonomic Function as a Physiological Mechanism Underlying the Reported Effects of Ashtanga Yoga: Feasibility and Initial Effectiveness Study

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By

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ABSTRACT

The recent widespread appeal of yoga highlights the importance of empirically assessing the ways in which it can improve psychophysiological health. A major limitation in the growing body of yoga research is the wide variability in what is considered "yoga." This interferes with the interpretation of results and with the identification of yoga's mechanisms of action. Ashtanga yoga addresses this limitation by being a set system of poses, making the practice a stable independent variable, ideal for empirical investigation. Ashtanga also is the only style of yoga that is practiced under the tristana, a method that integrates exercise, controlled breathing, and gaze, which induces the first stage of meditation. Additionally, Ashtanga yoga's unique aerobic/resistance properties are known to affect the autonomic nervous system by increasing parasympathetic activity. The aim of the present study was to explore the potential relation between the autonomic nervous system and the previously reported beneficial effects of Ashtanga yoga on psychological well-being using a pre-/post-study design. Twenty-four healthy participants completed 6-weeks of twice weekly Ashtanga yoga. The results confirmed Ashtanga yoga's effectiveness for improving psychological well-being and demonstrated that these improvements are associated with improvements in autonomic function. Findings are consistent with proposed theories of the physiological mechanisms of change in the practice of yoga, and they provide the first empirically supported evidence for the association between autonomic function and the psychological benefits of Ashtanga. The next step is to conduct randomized controlled trials to replicate these results and establish causality.

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LIST OF TERMS AND ABBREVIATIONS

ANS	Autonomic nervous system
Asana	Third limb of the Yoga Sutras; physical/yoga posture
BDI	Beck Depression Inventory
Bhandas	Activation of specific isolated muscle groups
BP	Arterial blood pressure
Bpm	Beats per minute
CGSA	Course graining spectral analysis
DBP	Diastolic blood pressure
Dharana	Sixth limb of the Yoga Sutras; initial stage of meditation or maintaining focused attention
Dhyana	Seventh limb of the Yoga Sutras; meditation
Dristi	Gaze or point of visual focus
ECG	Electrocardiography
FFMQ	Five Facet Mindfulness Questionnaire
FFT	Fast Fourier transform
GABA	Gamma-aminobutyric acid
Hatha	Yoga with a physical component that does not include fluid transitions between poses
HF	High frequency (HRV frequency band, 0.15–0.4 Hz)
HIIT	High intensity interval training
HR	Heart rate
HRV	Heart rate variability

IIP	Inventory of Interpersonal Problems
LF	Low frequency (HRV frequency band, 0.04–0.15 Hz)
MCAR	Missing completely at random
MI	Multiple imputation
MHR	Maximum heart rate
mmHg	Millimeters of mercury
Niyama	Second limb of the Yoga Sutras; self-discipline
PANAS	Positive and Negative Affect Schedule
PNS	Parasympathetic nervous system
Pranayama	Fourth limb of the Yoga Sutras; controlled breathing
Pratyahara	Fifth limb of the Yoga Sutras; conscious effort to draw awareness away from the external world and outside stimuli
PSS	Perceived Stress Scale
RMSSD	Root mean square of successive R-R interval differences
RSES	Rosenberg Self-Esteem Scale
R-R	Time interval between successive ECG R-waves (R-R interval)
Samadhi	Eighth limb of the Yoga Sutras; final stage of meditation in which a blissful state of interconnectedness with everything in the universe is achieved
SBP	Systolic blood pressure
SNS	Sympathetic nervous system
STAI	State-Trait Anxiety Inventory
SSES	State Self-Esteem Scale

Tristana	Threefold approach to Ashtanga yoga (pranayama, asana, dristi)
Vinyasa	Breath synchronized movement
VLF	Very low frequency (HRV frequency band, 0–0.04 Hz)
Yama	First limb of the Yoga Sutras; ethical standards and sense of integrity

CHAPTER I.

INTRODUCTION AND LITERATURE REVIEW

1.1 General Introduction

Popular interest in yoga has risen sharply in recent years, as has scientific investigation of its various forms. An American community census survey revealed that in the last four years alone the number of yoga practitioners, defined as individuals who had practiced yoga at least once in the past six months, increased by over fifty percent with approximately 37 million Americans practicing yoga today (Ipsos Public Affairs, 2016). Over half of the census participants cited improved overall health as the primary reason to start and continue practicing. Generally, research supports the effectiveness of yoga for enhancing psychological and physical functions such as improved mood and reduced risk for cardiovascular disease (Cramer et al., 2014; Cramer, Lauche, Langhorst, & Dobos, 2013).

A major limitation in the growing body of yoga research is the wide variability in what is considered “yoga” in published studies. Assuming that yoga can be thought of as a singular hypothetical construct, this makes it difficult to develop a replicable, cohesive and incremental set of empirical findings such that yoga’s mechanisms of action can become progressively better understood. Before discussing potential physiological mechanisms, it is important to understand the historical and philosophical foundations of yoga that span over two thousand years, as doing so will provide insight into its recent surge in popularity and need for high quality empirical research.

1.2 Historical and Philosophical Foundations of Yoga

The major principles of the philosophical system of yoga originated in India and were formally systematized by the Yoga Sutras of Patanjali approximately 2000 years ago (De Michelis, 2005). *Yoga* originates from the Sanskrit word, *yuj*, meaning to integrate the physical or individual self with the spiritual or universal self (Schonfeld, 2014). In other words, yoga is a lifestyle that aims to balance the mind, body, and spirit (Saraswati & Hiti, 1996).

Traditionally, in yoga philosophy, it is believed that adhering to eight principles leads to a calm mind and the alleviation of mental distress (De Michelis, 2005; Feuerstein, 1998; Hartranft, 2003; Iyengar, 1979). These eight principles are called the 'Eight Limbs of Yoga' (De Michelis, 2005). The first two limbs (*yama* and *niyama*) consist of ethical rules and behaviours, such as nonviolence and self-discipline (Hartranft, 2003). The third and fourth comprise *asana*, a Sanskrit word meaning physical posture or yoga posture (Lowitz & Datta, 2009), and controlled breathing (*pranayama*), respectively (Hartranft, 2003). The fifth (*pratyahara*) consists of controlling sensory input or not letting oneself be distracted by surrounding stimulations (Hartranft, 2003). The sixth (*dharana*) consists of the initial stage of meditation or maintaining focused attention and concentration (Hartranft, 2003). The final limbs comprise more advanced levels of meditation (Hartranft, 2003). Specifically, the seventh limb (*dhyana*) is a state of absorption in which one's perceptual attention is directed entirely toward an object (Hartranft, 2003). The eighth limb (*samadhi*) is the highest level of meditation or an integrative state in which the object is deemed inseparable from the self (Hartranft, 2003). Here, the "object" is the entire notion of the universe to which the self is experienced as “joined” completely; this is the ultimate meaning of yoga. When one achieves this understanding, it is thought that the ego “dissolves” and the perception of deep connectedness, free from the boundaries of individual identity, creates a sense of bliss (Hartranft, 2003).

Early modern yoga teachers developed medical applications of yoga postures and breathing practices for treatment and therapeutic purposes (Singleton, 2010), and the global spread of yoga resulted in adaptations of the practice that reflect the health needs of modern society, such as weight loss and increased longevity. Presently, the term *yoga* is not protected or legislated, so there are many non-traditional exercise practices that call themselves yoga. Although many contemporary yoga styles have moved away from the ethical behavioural prescriptions of the Yoga Sutras, certain elements continue to endure in traditional styles of yoga. Specifically, in traditional forms of yoga the emphasis remains on all eight limbs of the Yoga Sutras, with the goal of inducing a meditative state.

Over the last 150 years, yoga practices have split into two broad clusters of styles: traditional yoga and non-traditional or contemporary styles of yoga. Traditional forms of yoga, such as Ashtanga yoga (see below for more on Ashtanga Yoga), have maintained the lifestyle approach such that practitioners of this style are encouraged to adhere to the eight limbs of the Yoga Sutras in their daily life. Contemporary styles of yoga such as Power Yoga, a Western variation of Ashtanga, tend to deemphasize the traditional lifestyle approach and instead emphasis is on physical activity as a means of maintaining and improving physical health. The growing focus on asana, or the physical component of yoga, led to a gradual transformation of the meaning of the word *yoga* itself. Its subsequent present-day misuse is one of the reasons the practice is primarily thought of as a physical exercise with a spiritual component, rather than a spiritual practice with a physical component.

Yoga continues to gain popularity as a complementary therapy and its widespread appeal highlights the importance of empirically assessing the ways in which it can improve psychological and physical health. Research on yoga is particularly important given the ease with which its physical poses or postures can be modified. For instance, postures can be adapted for children and the elderly (Benavides & Caballero, 2009; Patel, Newstead, & Ferrer, 2012). Yoga also can be practiced safely by individuals with chronic debilitating illnesses, such as arthritis, heart failure, and cancer (Buffart et al., 2012; Cramer, Lange, Klose, Paul, & Dobos, 2012; Krishna et al., 2014; Pullen et al., 2008; Ward, Stebbings, Cherkin, & Baxter, 2013). Furthermore, yoga does not require expensive equipment and practicing at home can be an inexpensive and convenient option for those who cannot afford the time or money to go to classes at a studio. Thus, empirically supported interventions that are accessible to virtually anyone, such as yoga, may be especially helpful for individuals seeking methods that can improve their psychological well-being and physical health.

1.3 Components of Traditional Yoga

Several contemporary styles of *Hatha* (yoga with a physical component that does not include fluid transitions between poses) have emerged that focus primarily on varying degrees of pranayama and asana. For example, Sudarshan Kriya yoga is a type of controlled breathing practice meant to calm the mind and body with alertness (Zope & Zope, 2013), whereas Anusara yoga is heavily focused on body alignment (Jain, 2012).

Although these and other contemporary styles of yoga do encompass asana or physical movement, many forms do not incorporate breathing techniques, nor a meditation period. Yet it is the integration of these three components – pranayama, dhyana, and asana – that may make traditional yoga styles particularly unique at improving psychological well-being.

1.3.1 Controlled breathing. As mentioned, controlled breathing or pranayama is one of three major components in traditional styles of yoga. Controlled breathing refers to voluntary breathing in which an individual purposely varies the frequency, depth, and pauses of respiration (Bhagat, Kharya, Jaryal, & Deepak, 2017). In contrast, spontaneous or automatic breathing is primarily controlled by neurons in the brainstem (West & Luks, 2016). Because the brain (cortex *and* brainstem) is responsible for the control of respiration, cortical factors such as pain, emotion, and temperature also affect respiratory rate. For example, the perception of fear or anxiety may trigger automatic processes in the brainstem that stimulate respiration (e.g., hyperventilation; West & Luks, 2016). Because it is possible to have some control over breathing, such as purposefully taking long, deep breaths, the cortex can override the brainstem to a degree (West & Luks, 2016). In other words, controlling respiratory rate may counteract the automatic stimulation induced by perceived or real negative stimuli by forcing the body to maintain cardiopulmonary homeostasis, producing a calming effect.

Controlled breathing is accompanied by important modifications of cardiopulmonary function that have empirically demonstrated health benefits (Lötters, Van Tol, Kwakkel, & Gosselink, 2002; Smart, Giallauria, & Dieberg, 2013; Twal, Wahlquist, & Balasubramanian, 2016). For example, in a meta-analysis investigating the effects of controlled breathing in patients with chronic obstructive pulmonary disease, Lötters et al. (2002) concluded that controlled breathing improves respiratory muscle strength and endurance, as well as decreases in the sensation of dyspnoea (laboured breathing). Similarly, in a meta-analysis of randomized controlled trials (RCTs) examining the efficacy of controlled breathing in chronic heart failure patients, Smart et al. (2013) found that controlled breathing is as effective as conventional exercise training in improving cardiorespiratory fitness and quality of life.

Another body of evidence suggests that controlled breathing also may be beneficial for psychological health. For example, the results of a meta-analysis of 10 RCTs (Cabral, Meyer, & Ames, 2011) investigating the effectiveness of yoga as a complementary treatment for major psychiatric disorders such as anxiety and posttraumatic stress disorder suggest that the controlled breathing component of yoga may be especially useful when treating these psychiatric disorders and their associated symptoms. Thus, styles of yoga that incorporate pranayama (controlled breathing) may be beneficial for maintaining and improving psychological well-being.

1.3.2 Meditation. Meditation or dhyana is another major component in traditional yoga. Meditation refers to techniques that attempt to focus attention in a nonanalytical manner, void of ruminative thought (Shapiro, 1982). Like yoga, the term “meditation” often is broadly used and encompasses many techniques that generally fall into two categories: focused attention meditation and open monitoring meditation (Lutz, Slagter, Dunne, & Davidson, 2008).

Focused attention meditation refers to the practice of maintaining one’s attention on a perceptual object (such as respiration rate or depth) by concentrating on the object to circumvent wandering thoughts (Lutz et al., 2008; Tops, Boksem, Quirin, IJzerman, & Koole, 2014). Mindfulness meditation belongs to this category (Gunaratana, 1991). This results in a narrow field of attention that allows the meditator to become detached from other internal or external stimuli such as depressive symptoms or environmental distractors (Lutz, Jha, Dunne, & Saron, 2015). Open monitoring types of meditation refer to practices that do not involve sustained attention on one specific object but instead the focus is to remain in the monitoring state; in other words, the aim of open monitoring is to be attentive to any experience that occurs without focusing on or judging these experiences (Lutz et al., 2008).

Although currently limited, there is some evidence suggesting that focused attention meditation may be beneficial for physical health. In their meta-analysis of nine RCTs examining the blood pressure response to mindfulness meditation, Anderson, Liu, and Kryscio (2008) found that mindfulness meditation was associated with reductions in systolic (~5 mmHg) and diastolic (~3 mmHg) blood pressure (BP; see below for more on arterial blood pressure) in normotensive and hypertensive individuals. The authors note that these findings should be interpreted with caution, however, as placebos were not available and double blinding was not possible in the studies.

The positive effects of focused attention meditation on psychological well-being has extensive empirical support. For example, a recent meta-analysis of 30 RCTs examining the effects of mindfulness meditation on chronic pain found it was associated with improvements in pain and depressive symptoms, as well as quality of life in these individuals (Hilton et al., 2016). Higher dispositional mindfulness also is associated with higher self-expression and empathy (Dekeyser, Raes, Leijssen, Leysen, & Dewulf, 2008).

Further, interventions aimed at increasing mindfulness skills improve interpersonal relations (Bihari & Mullan, 2014), suggesting that focused attention meditation may improve depression and interpersonal functioning or how one functions in social contexts.

In summary, focused attention meditation has been associated with numerous health benefits ranging from improved cardiovascular function to increased psychological well-being. Thus, yoga styles that incorporate dhyana (meditation) also may be beneficial for maintaining and improving psychological function.

1.3.3 Physical exercise. Physical exercise in the form of posture or asana is an integral component of many forms of yoga. Specifically, some styles of traditional yoga (such as Ashtanga) possess a unique aerobic quality, along with significant isometric and resistance properties (see below), that may make them a promising practice for improving overall health. Physical exercise helps to reduce elevated BP and maintain normal levels (Chobanian et al., 2003), which is of great importance given that hypertension or chronically elevated BP increases susceptibility to cardiovascular disease, the second leading cause of death in Canada and worldwide (Pescatello et al., 2004; Statistics Canada, 2017; World Health Organization, 2017). Indeed, an estimated 874 million people worldwide have hypertension (Forouzanfar et al., 2017), so investigating interventions that promote cardiovascular health are essential. Before discussing physical exercise and its associated benefits, it is important to understand the complex regulatory mechanisms that influence, sustain, and contribute to chronic exercise training adaptations of arterial BP in healthy individuals, as doing so will provide insight into the mind-body connection proposed in the present investigation.

Arterial blood pressure. The heart's primary function is to maintain pressure by producing high hydrostatic pressure to pump blood out of the heart while also generating low pressure to move blood back into the heart (Brooks, Fahey, & White, 1996). Thus, BP reflects the amount of pressure exerted on the arteries as blood moves through the body or the circulatory system (Figure 1). In order to move blood through the circulatory system, the heart contracts to a pressure greater than the resistance of the blood vessel walls; this is known as systolic BP (SBP). When the heart is at rest, blood exerts a decreased pressure on the walls of the arteries known as diastolic BP (DBP). These values are typically recorded as SBP/DBP and normal BP is <120/80 mmHg (Whelton et al., 2018).

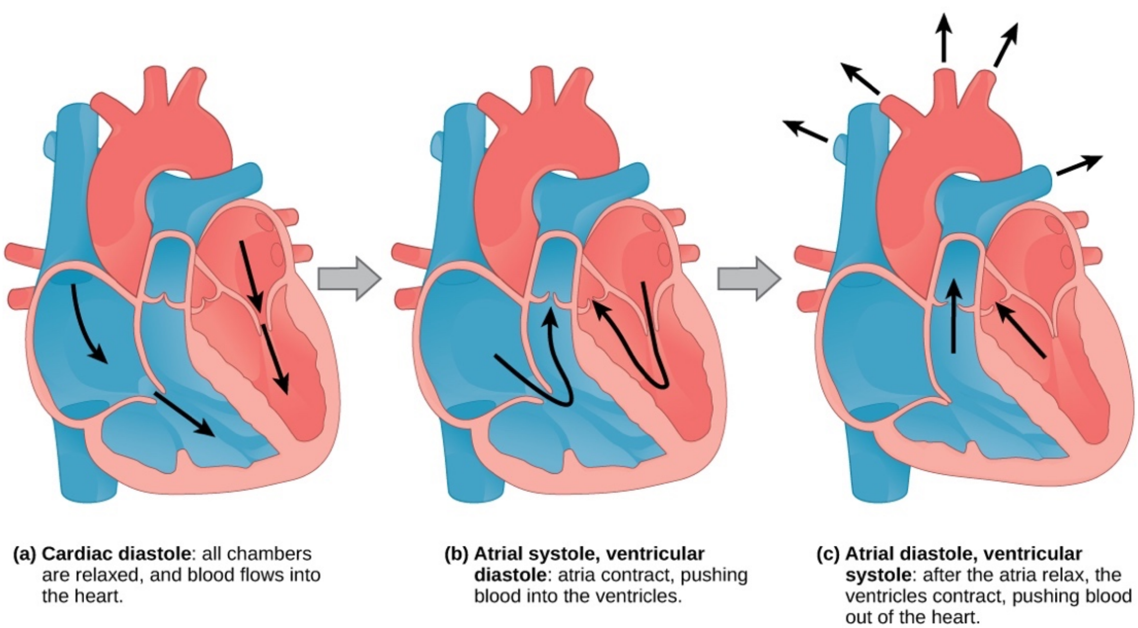

Figure 1. Arterial blood pressure. Adapted from OpenStax (2018).

In a healthy individual, a complete cardiac cycle (one beat of the heart) adequately supplies all organs and tissue with blood (Brooks et al., 1996). Neural, local, and hormonal regulatory mechanisms work together to sustain BP by influencing heart rate, stroke volume, and total peripheral resistance (i.e., the resistance of the blood vessel walls as blood is pushed through the circulatory system); blood pressure is the product of cardiac output (heart rate × stroke volume) and total peripheral resistance.

Neural mechanisms of blood pressure regulation. The neural regulatory mechanism that controls the cardiovascular system, located in higher brain regions, is known as central command (Brooks et al., 1996). When the body detects stress, central command sends neural (efferent) signals to the cardiovascular control center located in the brainstem, which activates the autonomic nervous system (ANS), with acute exercise stimulating its sympathetic division and chronic exercise training contributing to changes in its parasympathetic division (Laughlin, 1999). Note that this is a simplified description of a complex set of processes.

The ANS comprises two complementary sub-systems: the SNS, which is the primary regulator of BP, and the PNS, which regulates BP through its control of heart rate (HR; Brooks et al., 1996). For example, in response to cardiovascular stress such as exercise, the SNS first releases epinephrine and norepinephrine to stimulate cardiovascular response. Norepinephrine then binds to α-adrenergic receptors at the heart, which then increases HR by opening sodium and calcium ion channels, causing vasoconstriction (Tanoue et al., 2002). The PNS maintains homeostasis by simultaneously sending inhibitory neural impulses via the vagus nerve and various terminal nerve endings of PNS nerves. Finally, the norepinephrine that did not undergo reuptake binds to α2-adrenergic receptors at the heart, which then decreases HR by opening the ion channel flow, indirectly causing vasodilation (Brooks et al., 1996; Tortora & Grabowski, 2003).

Local mechanisms of blood pressure regulation. Another underlying regulatory process of BP occurs when muscles are contracted and/or blood flow increases (e.g., during exercise). When this occurs, local vasoactive substances that regulate vascular tone such as potassium, adenosine, and nitric oxide are released to stimulate vasodilation (the dilation, or expansion, of blood vessels), which increases the flow of oxygen to the tissues (Haddy & Scott, 1968). With the exception of high-intensity exercise, this local BP regulating process overrides the increase in sympathetic vasoconstriction (the constriction or narrowing, of blood vessels) that results from rising exercise intensity (Brooks et al., 1996; Delp & O'Leary, 2004). When exercise reaches high-intensity, skeletal muscles are vasoconstricted to maintain BP (Brooks et al., 1996). Thus, vasodilators play an important role in BP regulation.

Hormonal mechanisms of blood pressure regulation. Several hormones work with these neural and local mechanisms to maintain BP regulation. For example, SNS neurons release norepinephrine and epinephrine via the adrenal gland, and in response to sympathoexcitation, norepinephrine indirectly promotes vasodilation and lowers BP; while epinephrine simultaneously stimulates receptors that promote vasoconstriction, thus increasing BP (Opie, 2004). Similarly, PNS neurons release acetylcholine, which binds to muscle receptors in the heart, indirectly causing decreases in myocardial contractility (the ability of the heart muscle to contract) and thus decreases in BP (Brodde & Michel, 1999).

Several other hormones also influence BP regulation such as renin (secreted by the kidneys), which stimulates the other modulating hormones (Viera, 2007). Renin is a glycoprotein enzyme that interacts with angiotensinogen and together they form angiotensin I, an inactive protein that then is split into angiotensin II, the active form (Carey & Siragy, 2003). Angiotensin II is a vasoconstrictor and thus increases BP by increasing total peripheral resistance. This hormone also acts to increase BP by increasing fluid intake when an individual is thirsty. This process is then followed by inhibitory effects of arterial baroreceptors and thus BP is decreased (M. McKinley & Johnson, 2004).

Arterial baroreceptors are receptors in the heart that detect changes in BP based on the magnitude of stretch (Sherwood, 2001). If BP exceeds a set-point, inhibitory impulses are sent to the cardiovascular command centre which reduces sympathetic drive, resulting in decreased BP to lower set-point values (Brooks et al., 1996). Should BP fall below set-point values, baroreceptors reduce afferent discharge to the central command centre, which increases sympathetic drive, leading to increased BP.

Angiotensin II stimulates the adrenal cortex to release aldosterone, which stimulates the kidneys to increase reuptake of sodium (McLaughlin, Stamford, & White, 2007). Fluid volume in the body is increased as a result of the change in the ion concentration caused by this retention of sodium, which increases blood volume, leading to increased BP.

Vasopressin is secreted by the posterior pituitary gland and either induces vasoconstriction, causing increased BP, or it regulates fluid balance by increasing water volume excreted by the kidneys, which decreases BP (Courtice, Kwong, Lumbers, &

Potter, 1984; Henderson & Byron, 2007). The final process discussed here involves natriuretic peptide, which interacts with several hormones. It decreases sodium reabsorption in the kidneys, facilitating decreased fluid volume, leading to increased BP (McLaughlin et al., 2007). Natriuretic peptide also inhibits the secretion of renin, aldosterone, and vasopressin, which decreases BP (Antunes-Rodrigues, McCann, Rogers, & Samson, 1985).

In summary, BP regulation is influenced by a complex set of neural, local, and hormonal systems. Dysfunction in one or more of these systems increase vulnerability to hypertension (chronically elevated blood pressure). Given the prevalence of hypertension in the general population, and that psychological variables such as anxiety and depression also are risk factors for hypertension (Pan et al., 2015), it is important to investigate potential avenues for establishing and maintaining BP homeostasis. Exercise is one method through which the neural, local and hormonal mechanisms of BP can be effectively managed (Pescatello et al., 2004; Whelton et al., 2018). Exercise is thought to alter total peripheral resistance, which is increased in chronically diseased individuals (Ehrman, Gordon, Visich, & Keteyian, 2018; Pescatello et al., 2004). Increases in total peripheral resistance cause the heart to work effortfully to overcome the higher resistance and to adequately supply the body with blood (Ehrman et al., 2018). If sustained, this chronic overcompensation of the heart to establish and maintain BP homeostasis eventually can lead to heart failure (Ehrman et al., 2018).

To elicit the neural, local, and hormonal health benefits associated with exercise, the Canadian Society of Exercise Physiology (2018) recommends that adults engage in moderate- to vigorous-intensity aerobic exercise for at least 2.5 hours per week, in bouts of 10 minutes or more. Post-exercise reductions depend on baseline resting BP such that individuals who have high resting BP at baseline will experience the greatest reductions in BP due to aerobic exercise training (Cornelissen, Buys, & Smart, 2013; Huai et al., 2013). As an alternative method for lowering BP, Hypertension Canada recommends isometric exercise training (a form of resistance training that involves contracting muscles without dynamic movement) using an isometric handgrip device (Pescatello, MacDonald, Lamberti, & Johnson, 2015). Specifically, they recommend two-minute sustained (static) contractions at 30% of an individual's maximum strength, with each contraction separated by a 12–15-minute rest period, at least three times per week.

Aerobic exercise. Aerobic or endurance exercise refers to purposeful exercise that involves major muscle groups, is continuous and rhythmic in nature, and increases respiratory and heart rate (American Heart Association, 2018; Cowen & Adams, 2007; Garber et al., 2011). This includes activities such as swimming, cycling, jogging, walking, and some styles of yoga (American Heart Association, 2018; Cowen & Adams, 2007). During a bout of aerobic exercise, such as high intensity exercise, SBP can reach values of > 200 mmHg in order to adequately supply the active muscles with blood (Laukkanen et al., 2004; McArdle, Katch, & Katch, 2010). In response to this rising SBP, the active muscles work to lower SBP through vasodilation. This reduces total peripheral resistance to levels below a set-point, and BP eventually adapts to the training by lowering the resting set-point (Laughlin, 1999). Following aerobic exercise training (4–52 weeks; median ~16 weeks, 1–7 days per week), normotensive individuals have been shown to exhibit average decreases in resting BP of ~3 mmHg (SBP) and ~2 mmHg (DBP; Pescatello et al., 2004).

Aerobic exercise training also improves autonomic function by increasing vagal modulation of HR and decreasing sympathetic outflow (Rosenwinkel, Bloomfield, Arwady, & Goldsmith, 2001). Specifically, during acute aerobic exercise, vagal tone decreases and sympathetic activity increases, which leads to increased HR. Following aerobic exercise training, however, the ANS responds to the consistent rising HR during bouts of exercise by altering autonomic balance toward parasympathetic predominance (Hautala, Kiviniemi, & Tulppo, 2009). Some studies have shown that chronic aerobic exercise training is associated with increased vagal modulation of HR (e.g., Carter, Banister, & Blaber, 2003; Melanson & Freedson, 2001), whereas other studies have failed to find associations between ANS function and aerobic training (e.g., Boutcher & Stein, 1995; Loimaala, Huikuri, Oja, Pasanen, & Vuori, 2000).

Several reasons may explain these contradictory results, such as the complexity of long-term adaptations to regular aerobic training, intensity of exercise, small sample size, or the duration and/or frequency of interventions (Hautala et al., 2009). Sandercock, Bromley, and Brodie (2005) conducted a meta-analysis on the effects of exercise on autonomic function and found that, at minimum, 4-week aerobic training interventions are needed to detect significant changes in autonomic function. They also concluded that age plays a large role in these effects, with attenuated parasympathetic responses to aerobic training in older adults.

Isometric resistance exercise. Isometric exercise refers to activities during which contracting muscles develop force without shortening (Stefadouros, 1983), such as the whole body isometric muscular contractions that occur during yoga asanas. This type of sustained voluntary muscle contraction occludes (stops) blood from flowing to the active muscle and stimulates SNS activity, which increases HR in an attempt to adequately supply the contracting muscle with blood (Mark, Victor, Nerhed, & Wallin, 1985; Mayo & Kravitz, 1999).

Specifically, the occluded blood flow during acute bouts of isometric resistance exercise results in a build-up of metabolites (e.g., potassium, lactic acid, hydrogen ions, adenosine), which stimulates a system called the exercise pressor reflex to send afferent signals to central command, resulting in increased SNS activity (Smith, Collins, Ferrari, Holmes, Logstrup, & Zoghbi, 2005). Increases in intramuscular compression and resistance are accompanied by a rise in HR to provide more blood to the active muscles, and the blood supply eventually exceeds the amount needed to meet the metabolic demands (Laughlin, 1999).

Similar to aerobic training, chronic adaptations to isometric resistance exercise may be influenced by several factors, including duration and frequency of interventions, as well as demographic variables. For example, improved vagal modulation and reductions in SNS activity were found in a hypertensive sample following 10 weeks of isometric handgrip training (Taylor, McCartney, Kamath, & Wiley, 2003). In contrast, improvements in SBP, but not autonomic modulation, were found in a normotensive sample following 4–8 weeks of isometric handgrip training (Hanik et al., 2012). Finally, Inder et al.'s (2016) recent meta-analysis of isometric resistance training in healthy samples concluded that the magnitude of effects did not differ based on sex, age, or BP status. Thus, it appears that isometric resistance exercise may have beneficial effects on BP and autonomic modulation, but the variables contributing to the magnitude of such effects remain unclear. In general, however, normotensive individuals have been shown to exhibit reduced SNS activity and average decreases in resting BP of ~10–12 mmHg (SBP) and ~3–14 mmHg (DBP) following > 24 months of twice weekly isometric exercise training (Millar, Bray, MacDonald, & McCartney, 2008; O'Sullivan & Bell, 2000).

In summary, the empirical literature supports that different components of yoga practice contribute to physical and psychological well-being. Controlled breathing reduces psychological distress, improves nervous system function by improving autonomic balance, and increases quality of life, while meditation improves symptoms of depression and anxiety separately from breathing. Similarly, the widespread heart, and neural (autonomic) benefits of aerobic exercise suggest that isometric and resistance exercise support cardiovascular health.

1.3.4 Psychological benefits of exercise. Physical exercise also has been shown to confer psychological benefits such as decreased levels of depression and anxiety (Josefsson, Lindwall, & Archer, 2014; Knapen, Vancampfort, Moriën, & Marchal, 2015; Lindwall, Gerber, Jonsdottir, Börjesson, & Ahlborg, 2014). For example, a meta-analysis by Josefsson et al. (2014) found that exercise interventions have moderate to large antidepressant effects. The authors concluded that although the efficacy of exercise for improving depressive symptoms was persuasive, and exercise should be recommended for people with mild to moderate depression, it was not possible to determine the mechanisms by which the effects of exercise improved mood.

In a review of four meta-analyses, Knapen et al. (2015) not only found that exercise is an effective treatment for depression, but also that the effect of exercise may be comparable to that of antidepressant medication and psychotherapy for individuals with mild to moderate depression. For severe depression, they concluded that exercise is a beneficial complementary therapy.

The anxiolytic effects of exercise also have extensive support. For example, a meta-analysis of RCTs (Wipfli, Rethorst, & Landers, 2008) found that exercise alleviates anxiety, with a dose-response consistent with physical activity recommendations by the American College of Sports Medicine and Centers for Disease Control. The authors concluded that the results provided the highest level of evidence (Level 1, Grade A) for using exercise as a treatment for anxiety disorders. Thus, exercise boasts a myriad of physical and mental health benefits, and traditional styles of yoga that incorporate asana (physical poses) may be especially beneficial for maintaining and improving psychological well-being.

1.4 Physical Benefits of Yoga

The body of literature on yoga does not currently contain many studies that include physical health outcome variables measured via objective methods (e.g., blood pressure, electrocardiograph). Thus, the number of studies that examine physiological effects of yoga is small, and the data are inconsistent and therefore inconclusive. For example, in a meta-analysis investigating the effects of yoga on the physical health (self-reported pain, fatigue, sleep disturbances) of patients with cancer (Lin, Hu, Chang, Lin, & Tsauo, 2011), the authors concluded that no significant physical health differences occurred between yoga and non-yoga groups. Their results should be interpreted with caution, however, as the studies included in their analysis solely used self-report questionnaires to measure physical health.

Another meta-analysis of RCTs (Buffart et al., 2012) that compared patients with cancer to survivors of cancer concluded that Hatha yoga conveyed small, but beneficial effects for physical function and functional well-being such as pain and nausea when compared to non-exercise or wait-list control groups. Again, their results should be interpreted with caution as the majority of the studies included in the meta-analysis used self-report measures of physical health, and the few that used physiological markers, such as blood pressure, did not reach statistical significance. Thus, given the paucity of yoga research on markers of physical health, it is important that future research incorporate more objective physiological instruments when examining traditional styles of yoga to gain a better understanding of its efficacy and potential mechanisms of action.

1.5 Psychological Benefits of Yoga

In contrast to yoga's physical benefits, scholarly investigations widely support the benefits of various forms of yoga for psychological well-being. For example, several meta-analyses have demonstrated promising possibilities for the use of yoga to treat internalizing symptoms. One meta-analysis of nine RCTs (Cramer, Lauche, et al., 2013) assessed the effectiveness of various types of yoga (8–12 weeks, 1–7 days per week) for depression in patients with depressive disorders and individuals with elevated levels of depression. They reported moderate effects and concluded that all nine of the RCTs demonstrated evidence for short-term improvements in depression severity.

Evidence also is growing that yoga may improve perceived stress, self-esteem, and interpersonal problems, variables known to contribute to the development of depression and anxiety (Prinstein, Borelli, Cheah, Simon, & Aikins, 2005). Indeed, Kovačič and Kovačič (2011) investigated the effects of a 4-week, daily relaxation-based yoga intervention in 32 women with breast cancer. Patients were randomly assigned to a standard physiotherapy control group or to a standard physiotherapy plus relaxation-based yoga intervention group aimed at enhancing self-esteem and reducing perceived stress. The study demonstrated decreases in psychological distress in the yoga group, and increased distress in the control group.

In a more recent RCT, Kinser, Bourguignon, Whaley, Hauenstein, and Taylor (2013) investigated the effects of 8 weekly sessions of Hatha yoga on 27 women with major depressive disorder. Although improvements in depression did not reach significance when comparing the groups, qualitative analyses revealed that participants in the yoga group experienced an increase in positive mood that they attributed to feeling more connected to others, suggesting a positive effect of yoga in interpersonal relations. Therefore, as shown by the studies discussed, yoga appears to have widespread psychological benefits. Continued research is needed to further understanding of the physiological mechanisms that may underlie these psychological benefits, and Ashtanga yoga encompasses characteristics that may make it a unique stimulus for investigating such potential underpinnings.

1.6 Ashtanga Yoga

Ashtanga is the English translation of the Sanskrit word *aṣṭāṅga*, which means eight limbs (Oxford English Dictionary, 2006). As such, Ashtanga yoga is based on the eight principles of the Yoga Sutras. Ashtanga yoga is a unique heart rate-increasing traditional form of yoga that simultaneously combines meditation, aerobic and isometric resistance exercise, and controlled breathing within its practice. It is the only form of yoga practiced under the *tristana*, a threefold approach to yoga consisting of asana, pranayama, and gaze or a point of visual focus (*dristi*; Jarry, Chang, & La Civita, 2017).

The goal of the tristana is to achieve a meditative state or make the practice a moving meditation (Jois, 2010). Specifically, the complex nature of the postures requires careful focused attention on technique and the body's alignment. For example, keeping the knee on top of the ankle and engaging specific isolated muscles (*bhandas*). The second element, controlled breathing, consists of coordinating every inhalation and exhalation with the movements included in each posture and the transitions between them, also known as *vinyasa* or breath synchronized movement. For example, opening/expanding movements generally are made while inhaling, and folding/contracting movements are made when exhaling. At the same time, the practitioner focuses on a specific gazing point, such as the fingertips, to reduce external distractions. Thus, the fusion of asana, pranayama, and dristi leaves little room for the mind to wander and as such, it induces a state of focused attention or the first step of meditation and the goal of tristana is achieved. In other words, focused attention cultivates mental stillness and makes Ashtanga yoga a moving meditation with significant aerobic and isometric resistance properties. Further, unlike some other forms of yoga, Ashtanga involves no props, no mirrors, and no music, any of which may interfere with concentration and achieving focused attention.

1.6.1 Practice overview. As discussed above, a major limitation of existing yoga research is the wide variability in what is considered "yoga" in published studies. Contemporary adaptations of traditional styles of yoga are constantly being created with variations in elements such as asanas, asana sequencing, transition between asanas, emphasis on breath/movement coordination, use of props and music, teaching style, emphasis on strength versus flexibility, integration of breathing and meditation within or separately from the asana practice, and even room temperature. This makes it difficult to develop a replicable, cohesive and incremental set of empirical findings such that the knowledge of yoga's mechanisms of action can become progressively better understood. Ashtanga yoga is particularly well suited to address such limitations due to its standardized practice: by being comprised of a methodical system of poses, always practiced in the same order, in the same way, and with similar intensity of practice, such that its components can be isolated as stable independent variables, providing a greater level of control suitable for empirical investigation.

Ashtanga yoga comprises six series of postures of increasing difficulty: Primary, Intermediate, and four Advanced Series. The Primary Series includes 49 asanas, and many early yoga students often start only with the first half of this series. In all six series, the asanas are organized in an invariant order of increasing difficulty. Each pose is taught and practiced in progressive approximations until it is sufficiently mastered for progression to the next pose (Jarry et al., 2017). Careful technical instruction combined with individualized pace and adjustments makes the Ashtanga practice inherently adapted to practitioners' individual condition and protects from injury (see Cramer, Krucoff, & Dobos, 2013 for a review of potential adverse effects of yoga).

Ashtanga yoga is typically practiced six days per week and is taught either 'Mysore Style', named after the location in which Ashtanga was originally developed (Mysore, India) or in weekly group guided, 'Led,' classes. Each class begins with all practitioners joined in an "Om," followed by a traditional Sanskrit opening chant which expresses gratitude to all previous yoga teachers and a second “Om.” The “Om” involves slow breathing and airway resistance, by contracting the vocal cords to generate sound, which is thought to increase PNS activation (Brown & Gerbarg, 2005a, 2005b, 2009; Telles, Nagarathna, & Nagendra, 1995).

Next, practitioners complete the sun salutations followed by standing asanas, the sitting asanas, and then the finishing asanas (see Appendix A). In Mysore classes, practitioners are taught the sequence of asanas through one-on-one instruction by a trained teacher. All aspects of the practice such as correct alignment and vinyasas are learned in a progressive manner. Learning gradually allows time for practitioners to adjust as they develop strength, flexibility, and mental focus. Learning too much too quickly may bring the risk of injury; thus, practitioners are taught at a rate appropriate for each individual and modifications are available to suit individual needs. This style of teaching minimizes recall effort or having to listen to instructions, allowing each practitioner time to practice and memorize what they have learned before adding more. This means that for approximately 75-minutes, practitioners are absorbed in the tristana in a manner that excludes extraneous thoughts and promotes a meditative state.

For both new and experienced practitioners, weekly group guided classes, or Led classes, are an important complement to regular Mysore practice. In Led classes, practitioners learn to follow the teacher’s count and pacing, but must stop at the pose at which their Mysore practice usually stops. The format of these classes offers practitioners the opportunity to ensure that asanas and vinyasas are being learned and practiced correctly and at an optimal pace.

1.6.2 Aerobic intensity as a stimulus for change. As previously mentioned, Ashtanga is a traditional style of yoga that simultaneously combines meditation, aerobic and isometric resistance exercise together with controlled breathing within its practice. Indeed, a study that compared the effects of three different yoga styles on HR indicated that Ashtanga yoga can be considered a moderate-intensity physical exercise (Cowen & Adams, 2007). In this study, 16 non-clinical adults participated in two 80-minute sessions for each style of yoga (modified Ashtanga in which several of the more difficult poses were omitted, Hatha yoga, and a 'gentle yoga' class) while wearing wireless HR monitors. Those in the modified Ashtanga group had significantly higher mean HRs (100.69 beats per minute [bpm], 54% MHR) than those in either the Hatha yoga (83.37 bpm, 45% MHR) or gentle yoga (42% MHR) groups. No difference in HR was found between the Hatha yoga and gentle styles, suggesting that Ashtanga may be superior to other styles of traditional yoga in improving physical health. Note that because the more difficult Ashtanga poses were omitted in this study, HR was likely lower than what would be expected in an unmodified practice.

Although there are no published data regarding the within practice variation of Ashtanga yoga, pilot data from our laboratory suggests that Ashtanga yoga mimics that of high intensity interval training (HIIT). HIIT involves alternating between short bursts of high-intensity exercise (70–80% MHR) with recovery periods or light exercise (50–70% MHR; Weston, Wisløff, & Coombes, 2014). Thus, Ashtanga's chaining of poses by dynamic, fluid movements, coordinated with breathing, makes it a unique form of interval training aerobic exercise that may act as a distinctive set of behaviours that may promote psychophysiological change.

Published work from our research group has demonstrated the effectiveness of a 9-week, twice-weekly Ashtanga yoga program for enhancing psychological well-being using a pre-, mid-, post-treatment design (Jarry et al., 2017). The results indicated that providing training in Ashtanga yoga to novices led to significant improvements in self-esteem, symptoms of depression and anxiety, and in interpersonal functioning. Importantly, these findings were recently replicated in a subsequent randomized controlled trial, and improvements in focused attention were found to mediate these changes (Jarry, Howard, & Chang, under revision). Significant improvements in both studies occurred after only 5-weeks of practice. However, physiological variables were not assessed in these studies, hence potential physiological mechanisms by which Ashtanga yoga may confer some of its benefits remain unknown.

1.7 Potential Underlying Physiological Mechanisms of Psychological Improvements

While this evidence points to the beneficial effects of Ashtanga yoga on psychological well-being, the physiological mechanisms that contribute to people feeling subjectively better remain poorly understood. Why is it that people feel less stressed, experience improved mood, and experience better interpersonal functioning after an Ashtanga yoga intervention? Researchers have proposed physiological underpinnings such as hormone regulation (Field, 2011; Vera et al., 2009) circulatory system enhancements (Innes, Bourguignon, & Taylor, 2005), and increases in GABA activity (Streeter, Gerbarg, Saper, Ciraulo, & Brown, 2012). To date, however, no studies have been conducted to directly assess possible physiological pathways underlying the psychological benefits of Ashtanga yoga.

1.7.1 Improved autonomic nervous system function as a mechanism of psychological adaptation. The term *mechanism* refers to underlying processes that cause change (Kazdin, 2017); in this case, it refers to possible physiological processes by which Ashtanga yoga improves psychological well-being. Although as reviewed several physiological mechanisms have been proposed for the beneficial effect of various forms of yoga on psychological health (Dunn, 2008; McCall, 2013; Riley & Park, 2015; Streeter et al., 2012), few investigations have been conducted to assess these potential pathways. Further, the existing studies of possible physiological mechanisms were conducted on individuals with diseases such as irritable bowel syndrome (Evans, Cousins, Tsao, Sternlieb, & Zeltzer, 2011), individuals who were severely distressed, (Evans, Cousins, Tsao, Sternlieb, & Zeltzer, 2011; Michalsen et al., 2005; Yadav, Magan, Mehta, Sharma, & Mahapatra, 2012) or older populations (Kiecolt-Glaser et al., 2010), thus limiting the interpretability and generalizability of results to the general population.

Despite these limitations, there is a growing body of literature supporting the possible mediating effects of the ANS. For example, Vijayalakshmi, Madanmohan, Patil, and Babu (2004) demonstrated that yogic relaxation techniques decrease markers of sympathetic response (BP, HR) in hypertensive individuals following exposure to an experimental stressor. In another study, Streeter et al. (2007) demonstrated significant increases in gamma-aminobutyric acid (GABA) activity following a single 60 minute asana-based yoga session compared to a reading group, who showed no change. In a follow-up study, Streeter et al. (2010) compared a Hatha yoga intervention to a metabolically matched walking intervention to determine whether changes in GABA were specific to yoga or attributable to physical activity in general. The results indicated that the yoga intervention was associated with a greater increase in GABA activity, suggesting that the effect of the yoga intervention on GABA levels were not solely due to the metabolic demands of physical activity. Thus, it is likely that asana-based yoga attenuates sympathoexcitation and increases GABA activity through stimulation of the vagus nerve, the primary peripheral pathway of the PNS (Streeter et al., 2012).

Gamma-aminobutyric acid and parasympathetic activation. GABA is one of the primary inhibitory neurotransmitters of the brain, and it interacts with two general classes of receptors: $GABA_A$ and $GABA_B$ receptors (Leresche & Lambert, 2017; Tillakaratne, Medina-Kauwe, & Gibson, 1995). When GABA binds to the $GABA_A$ receptor it causes the opening of an associated ion channel that is permeable to the negatively charged ion chloride; when these ions flow into the neuron, they hyperpolarize the membrane potential of the neuron and thus inhibit the firing of an action potential (Bowery & Smart, 2006). When $GABA_B$ receptors are activated they cause the opening of potassium channels, which allow positively charged potassium ions to flow out of the neuron, again making the neuron hyperpolarized and less likely to fire an action potential (Bowery & Smart, 2006). With GABA being an inhibitory neurotransmitter, increased activity can have sedative/calming effects (Möhler, 2001). For example, a number of sedating drugs, such as alcohol and benzodiazepines, increase the GABA activity (Möhler, 2001).

On the other hand, empirical evidence suggests that underactivity of the PNS is correlated with diminished GABA activity, which further is associated with impaired emotion regulation, excessive threat perception, and several psychiatric disorders such as depression and anxiety (Goddard et al., 2001; Sanacora et al., 1999; Streeter et al., 2012). Although pharmacotherapy can increase activity of the GABA system (Abdou et al., 2006; Drugan et al., 1989), the use of GABA enhancing medications such as benzodiazepines has many potential adverse effects, including tolerance and dependence (Tan, Rudolph, & Lüscher, 2011). Therefore, non-chemical interventions that can improve parasympathetic tone and influence GABA activity are clearly worth investigating.

As discussed above, Ashtanga yoga concomitantly integrates aerobic/isometric exercise that mimics HIIT together with controlled breathing and meditation. These practices activate the PNS, inducing a sense of calm, and attenuating sympathoexcitation (Bhimani, Kulkarni, Kowale, & Salvi, 2011; von Haaren et al., 2016; Weippert, Behrens, Rieger, Stoll, & Kreuzfeld, 2013). Given the demonstrated influences of the ANS on the GABA system, it may be that increased PNS activity underlies the reported feelings of subjective well-being following yoga in general. Thus, Ashtanga yoga's aerobic quality and isometric/resistance properties, both of which may promote PNS activity, make it a suitable independent variable for investigating this proposed pathway.

1.8 Thesis Objectives

The present research sought to empirically investigate potential mechanisms by which Ashtanga yoga improves psychological well-being by exploring its possible association with the ANS. Indeed, the empirical evidence reviewed above suggests that changes in the ANS such as increased parasympathetic tone may be a mechanism by which yoga results in improved psychological function (Riley & Park, 2015; Streeter et al., 2012). Given that Ashtanga yoga combines meditation, aerobic and isometric resistance exercise together with controlled breathing within its practice, it may be the most appropriate yoga intervention for examining potential physiological mechanisms.

The aim of the present investigation was to conduct an intensive, single group, pre-/post-study design to explore the potential relation between improved ANS function such as increased PNS activity and improved autonomic balance and the reported effects of Ashtanga yoga on psychological well-being in a group of young adults (18–30 years). This narrow age range was chosen to better control for the detrimental influence of aging on the proposed outcome measures. In our previous Ashtanga intervention studies (Jarry et al., 2017; Jarry et al., under revision), we saw psychological benefits after 5 weeks; however, to maximize the potential for physiological changes via exercise training, the present investigation took place over 6 weeks.

1.9 Hypotheses

1) Participants will show significant improvements in psychological functioning (depressive and anxiety symptoms, perceived stress, self-esteem, interpersonal functioning, and mindfulness) from baseline to the end of a 6-week, twice weekly Ashtanga yoga intervention.

2) Participants will experience improvements in indices of autonomic function (i.e., increased parasympathetic activity) and improved autonomic balance (i.e., improved sympathetic/parasympathetic ratio) after participating in the intervention.

3) Improvements in autonomic function and autonomic modulation will correlate with improvements in psychological functioning following the intervention.

1.10 Summary of Background

In summary, the recent widespread appeal of yoga, as well as its increasing use as a complementary therapy, calls attention to the need for high quality investigation of its effects on psychological well-being and physical health. A major limitation in the growing body of yoga research is the wide variability in what is considered “yoga” in published studies, making the interpretation of results difficult. Ashtanga yoga addresses this limitation due to its standardized practice making it suitable as a controlled variable in systematic research. Ashtanga also is the only style of yoga that integrates physical exercise, controlled breathing, and gaze or a point of visual focus such that, when combined, they induce a state of focused attention. Finally, Ashtanga yoga concomitantly integrates unique aerobic and resistance properties that mimic HIIT. These practices likely affect ANS function by activating the parasympathetic nervous system, producing a sense of calm.

As discussed, yoga is an affordable and effective method for maintaining and improving psychological and physical health. Additionally, yoga has potential to reduce the need for certain medications, such as benzodiazepines, that are accompanied by detrimental side-effects. Understanding the physiological mechanisms by which Ashtanga yoga improves psychological well-being has far-reaching implications for public health. This knowledge also is critical for optimizing interventions for the treatment and prevention of myriads of diseases and their associated symptoms, such as psychiatric disorders and dysfunction of cardiovascular and pulmonary systems. Further, identifying the physiological mechanisms that contribute to Ashtanga yoga’s health benefits will help to propel the field of yoga research toward more nuanced investigations of its wide-ranging effects.

CHAPTER II.

METHODOLOGY

2.1 Participants

Twenty-four normotensive participants were recruited from Windsor, Ontario, Canada (see Figure 2 for a chart showing the participant flow). Recruitment consisted of a poster campaign on a university campus (Appendix B), a study website (www.theyogastudy.com) and a Facebook page. Inclusion criteria required individuals to be 18–30 years of age, have a resting systolic BP <135 mmHg and a resting diastolic BP <85 mmHg, be free from overt diseases, not currently taking prescription medication with the exception of birth control, and be available for twice weekly 75-minute yoga sessions for the duration of the study. Participants were excluded for the following reasons: if they had participated in a previous Ashtanga yoga intervention study, regularly practiced any form of yoga, had a current medical diagnosis (e.g., asthma) and/or were taking prescribed medications known to influence autonomic function (e.g., antidepressants), and/or had physical limitations that would impair their exercise performance. This information was collected verbally from the participants during their initial lab visit, as well as from the medical questionnaire completed at the same session (Appendix C).

Exercise, medication, and dietary changes were monitored throughout the investigation via log-book tracking (Appendix D) at each point of contact. At the end of each yoga class, participants received a ballot for entry into a draw for a “Yoga Essentials Kit,” which included a yoga mat, a mat bag, a water bottle, and an Ashtanga yoga DVD. The winner of the draw was randomly selected at the close of the study. All participants

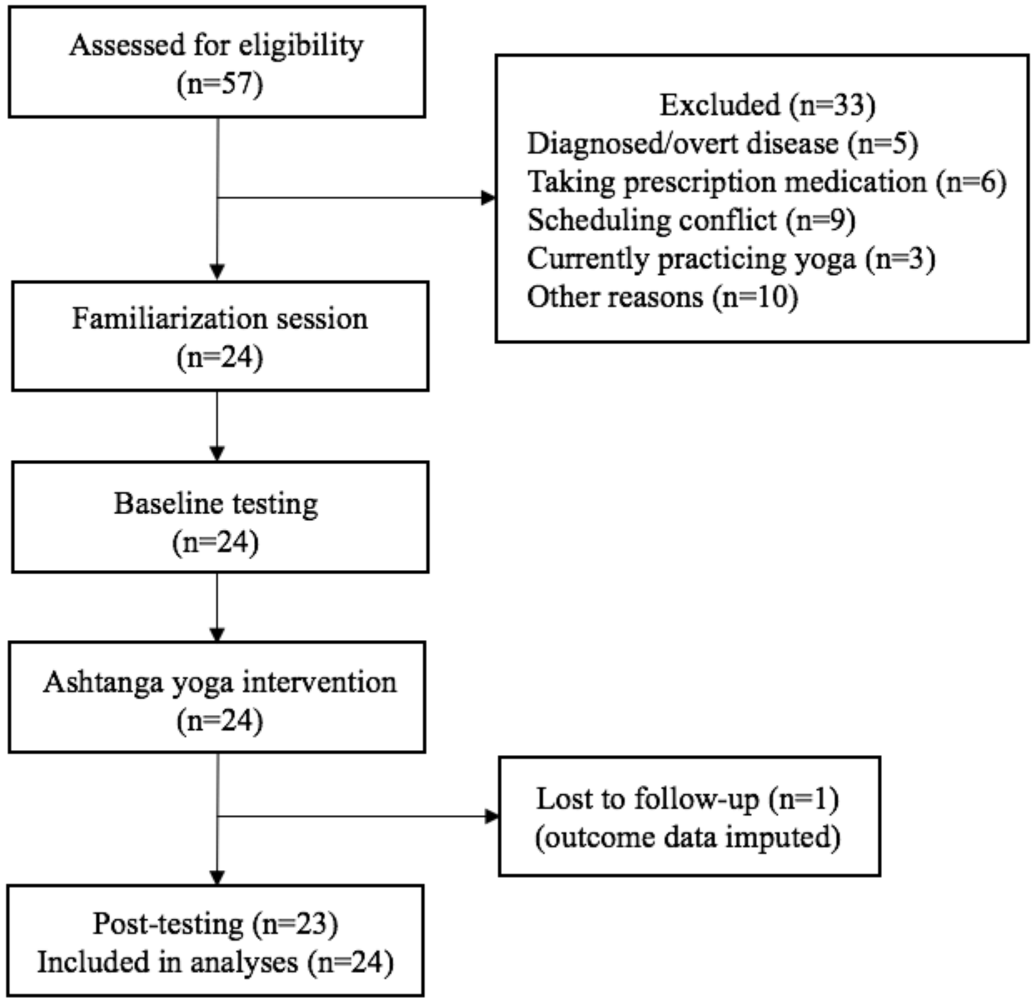

Figure 2. Participant flow chart.

were offered the choice of a research memento (e.g., t-shirt) upon completion of the study. The University of Windsor Research Ethics Board reviewed and cleared the study prior to data collection, and all participants provided signed informed consent.

2.2 Study Design

2.2.1 Eligibility and familiarization. Interested participants who thought that they met the required inclusion criteria contacted the researchers via email and arranged a time to meet at the Physical Activity and Cardiovascular Research (PACR) Laboratory (Room #240, Human Kinetics Building, University of Windsor). At the lab, the researchers explained all parts of the investigation to the potential participants (see Figure 3 for an overview of the study design). Participants then were asked to read the Global Consent Form (Appendix E) and if they remained interested in the study, they signed the consent form and received a copy for their records.

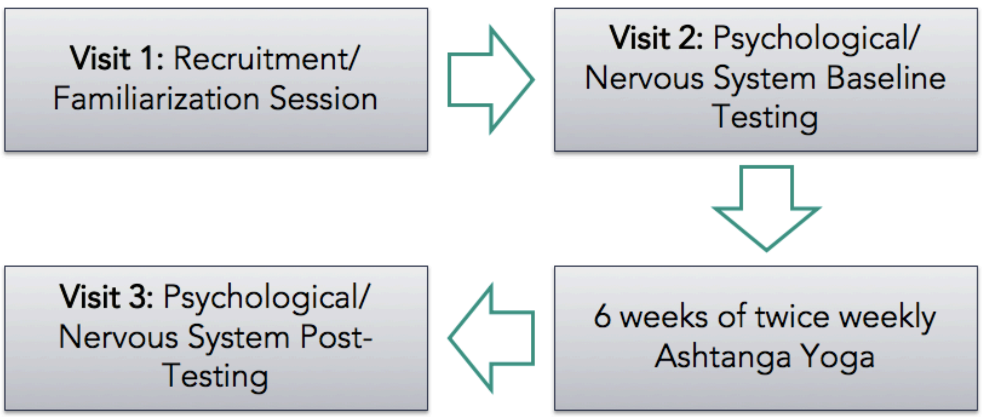

Figure 3. Overview of study design.

All consented participants completed the PAR-Q+ (Appendix C), a physical activity readiness questionnaire to determine any physical contraindications that may exclude them from the study. Participants confirmed that they had not consumed caffeine in the last 12 hours or alcohol in the last 24 hours. Next, resting arterial BP was measured via brachial artery oscillometry (Appendix F). Resting arterial BP and HR were measured following 10 minutes of seated rest according to standard laboratory protocols. Specifically, BP measurements involved the placement of a cuff around the dominant arm (upper portion), which was inflated to a pressure greater than systolic BP to occlude the brachial artery (Badrov, Millar, & McGowan, 2010). Arterial BP was measured four times, with a two-minute rest period between measures, and the last three values were averaged to assess eligibility. The BP data and the PAR-Q+ were used to determine eligibility of the potential participant for the study. At this time, any questions or concerns regarding the study were answered, and participants were informed of their right to withdraw from the study at any time. Eligible participants then completed a familiarization session where they had an opportunity to practice all portions of the lab testing procedures. This served to habituate participants to the testing protocol and minimize the effects of anxiety or unfamiliarity with the procedures on the outcome variables. Baseline participant characteristics are provided in Table 1.

2.2.2 Testing procedure. Prior to and following the Ashtanga yoga intervention, non-invasive tests of ANS function were performed followed by computer-based surveys of psychological variables (see Figure 4 for an overview of the testing protocol). Ongoing consent was confirmed at the beginning of each testing session. Pre- and post-testing sessions took place at the PACR Lab at the same time of day (within three hours), in a quiet, dark, temperature-controlled room (20–25ºC) following a two hour fast, 12-hour abstinence from caffeine, and 24-hour abstinence from alcohol and vigorous exercise (e.g., exercise that causes heavy breathing, an increased heart rate, and heavy sweating). Participants also were asked to void their bladder prior to testing to minimize the effects of bladder distension on resting BP (Fagius & Karhuvaara, 1989).

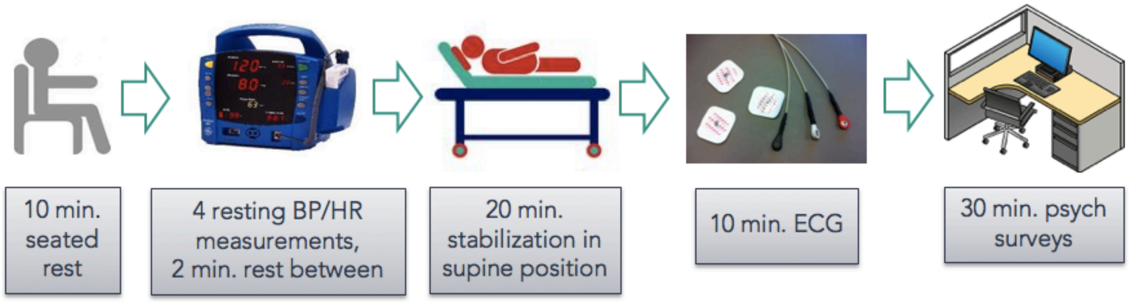

Figure 4. Overview of the testing protocol.

In brief, resting arterial BP and HR was measured after ten minutes of seated rest in the same manner as described above. Next, participants laid in the supine position (lying flat on one's back) on the laboratory bed and were fitted with electrodes to measure beat-to-beat heart rate. A respiratory belt was placed around the participants' abdomen to ensure spontaneous breathing through visual inspection of the computerized data. After a 20-minute stabilization period in the supine position, beat-to-beat HR was recorded for ten minutes via standard 3-lead echocardiography using a data acquisition system (Appendix G). These data were used for assessment of HRV. Participants then moved to a laboratory computer terminal to complete the psychological survey battery, which was administered using Qualtrics software (Appendix H). Each questionnaire included in the battery was presented in a system generated randomized order.

2.2.3 Ashtanga yoga intervention. Participants took part in twice weekly, 75-minute Ashtanga yoga classes over a period of six weeks, for a total of 12 classes or 15 hours. Ongoing consent was obtained and dietary, exercise, and medication status was recorded at the beginning of each class (Appendix D). Classes were taught by a Yoga Alliance registered instructor (YA-RYT-500) extensively trained in the traditional Ashtanga yoga method by a teacher authorized by the K. Pattabhi Jois Ashtanga Yoga

Institute. This teacher was assisted by a trained co-teacher. Each class began with a two to three-minute explanation of one of the ethical life prescriptions of the Yoga Sutras, after which all joined in an "Om," followed by the traditional Sanskrit opening chant and a second "Om." Participants then were invited to set an intention for their practice. This was followed by introductory dynamic poses from the traditional Ashtanga yoga Primary Series: Sun Salutations (Suryanamaskara A and B), Standing Asanas, Sitting Asanas up to Navasana, and Finishing Asanas. Each class ended with the closing chant also in Sanskrit, which wishes peace and happiness to all living beings, and the final resting pose.

The first eight classes progressively introduced the postures constituting the first half of the Primary Series. After the eighth class, the remaining four classes were identical to the eighth: participants were led through the half primary series and progressively trained to improve their technique, strength, flexibility and attentional focus. Each posture was taught in its integral form, followed by beginners' level modifications consistent with Swenson (1999). Teaching was tailored to each participant's capacity and limitations. Modifications were taught to participants who could not readily adopt a new pose or who had difficulties performing the transitions between poses. The instructor and assistant provided hands on adjustments during classes as is customary in Ashtanga yoga.

Table 1. *Baseline Characteristics of Participants (N=24)*

Characteristic	Mean (*SD*) or *n* (%)
Age (years)	22.21 (2.70)
Sex	
Female	19 (79.2%)
Male	5 (20.8%)
Height (cm)	169.98 (5.94)
Weight (kg)	67.68 (9.16)
BMI (kg/m^2)	23.40 (2.80)
Ethnicity	
Caucasian/White	18 (75%)
Other	6 (25%)
Marital Status	
Single	22 (91.7%)
Married/Common Law	2 (8.3%)
Student	21 (87.5%)
Undergraduate	14 (58.3%)
Graduate	7 (29.2%)
Resting Systolic BP (mmHg)	103 (6)
Resting Diastolic BP (mmHg)	62 (5)
Heart Rate (beats/min)	71 (9)
Experience with Ashtanga yoga	
No experience	22 (91.7%)
Tried it once	1 (4.2%)
No response	1 (4.2%)
Intervention Attendance (classes)	9.88 (1.48)

Note. BMI = body mass index; BP = blood pressure.

2.3 Measures of Autonomic Function

Brachial artery oscillometry (Dinamap Carescape v100, Critikon, Tampa, Florida, USA; Appendix F) was used to measure resting arterial BP according to standard laboratory protocols. Specifically, a BP cuff (25–35 cm arm circumference) was placed around the dominant arm (upper portion) approximately 2.5 cm proximal to the antecubital fossa (Figure 5; Pan American Hypertension Initiative, 2003).

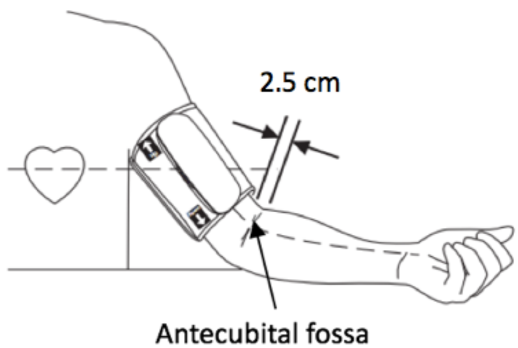

Figure 5. Blood pressure cuff placement.

The arm was then adjusted in the anatomical position at heart level. Participants were instructed to keep their feet flat on the floor and to remain as still as possible (Pickering et al., 2005). After 10 minutes of seated rest, the BP cuff was inflated to a pressure greater than systolic BP to occlude the brachial artery (Badrov et al., 2010). Four measurements were obtained, each separated by a two-minute rest period (True Consortium, 2017). To account for startle reflexes at the onset of the first cuff inflation, as well as potential white coat hyper/hypotension (Pickering et al., 1988), the last three values were averaged for analyses.

An electrocardiograph (ECG) was used to obtain continuous HR and pulse (R-R) intervals for later HRV assessment according to standard laboratory protocols. Three electrodes were placed on the chest: two were positioned under the left and right collarbones, and one was positioned under the left-hand side of the rib cage (Lead II configuration; Figure 6) and R-R interval HR data was recorded for 10 minutes, after 20 minutes of rest in the supine position. R-R interval HR data was recorded for 10 minutes, after 20 minutes of rest in the supine position. Signals were sampled at a frequency of 200 Hz, with the exception of the ECG signal (1,000 Hz), and a data acquisition board (PowerLab ML 870/P, ADinstruments, Colorado Springs, Colorado, USA; Appendix G) was used for analogue to digital signal conversion for off-line beat-to-beat analysis, where applicable (Stiller-Moldovan, Kenno, & McGowan, 2012).

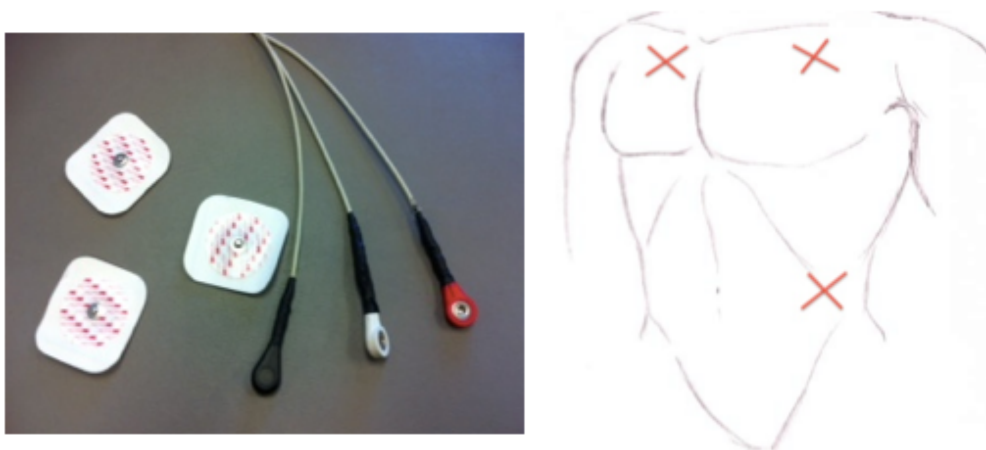

Figure 6. Lead II electrode configuration. ADinstruments, Colorado Springs, Colorado, USA.

2.3.1 Measuring autonomic nervous system activity via heart rate variability. One of the most promising non-invasive indicators of ANS function is heart rate variability (HRV), which can be measured using an electrocardiographic (ECG) method to assess the sympathetic and vagal balance of the ANS at the sinoatrial level (Sztajzel, 2004). ANS function is reflected in variations of both HR and the time interval between QRS complexes of normal sinus depolarizations or successive ECG R-waves (R-R intervals; Figure 7), with low HRV reflecting underactivity of the PNS (Stein, Bosner, Kleiger, & Conger, 1994; van Ravenswaaij-Arts, Kollee, Hopman, Stoelinga, & van Geijn, 1993). The standard parameters used to measure HRV are time domain and frequency domain indices (Kamath, Watanabe, & Upton, 2012).

Time domain analysis. Time domain variables are markers of overall HRV as they evaluate the alterations in HR between successive cardiac cycles (Kamath et al., 2012). A commonly used time domain variable is the standard deviation of normal-to-normal R-R intervals, which is influenced by both SNS and PNS activity. The two main limitations of the time domain parameter, however, are (1) that valid interpretation relies on homogenous R-R interval recordings (i.e., all intervals are the same length of time), and (2) its inability to discriminate between sympathetic and parasympathetic contributions to HR modulation; fortunately, frequency domain variables have the capacity to be used to estimate this information, even when R-R interval recordings are heterogenous (Kamath et al., 2012).

Frequency domain analysis. Frequency domain or power spectral analysis decomposes HR signals into its frequency components and quantifies their intensity or power (Kamath et al., 2012). Power is characterized via three frequency bands: *very low*

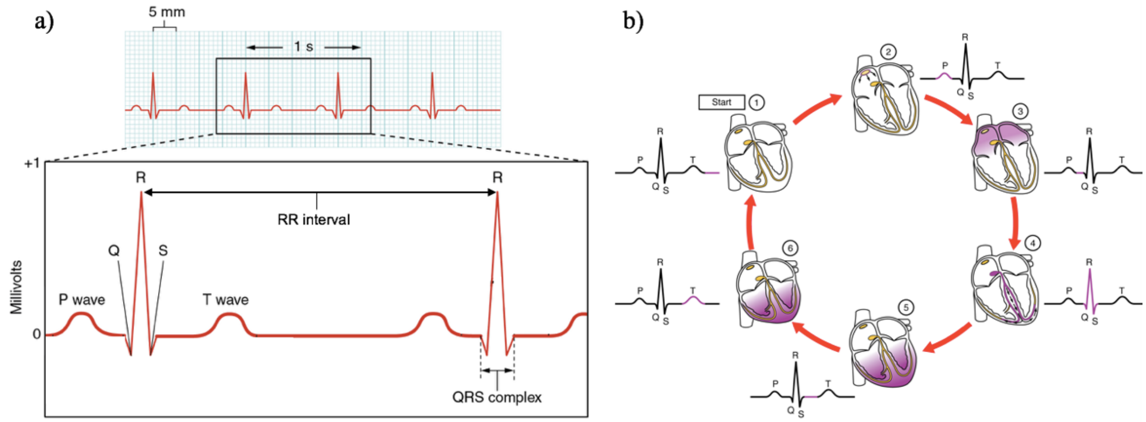

Figure 7. Electrocardiogram tracings; (a) A normal tracing in an electrocardiogram shows the P wave, QRS complex, T wave, and R-R interval; (b) ECG tracings correlated with one cardiac cycle; each segment corresponds to one electrical/mechanical event. (1) The sinoatrial (SA) node is at rest. (2) The SA node initiates the action potential (P wave). (3) A delay of approximately 100 milliseconds (ms) as the atria finishes pumping blood. (4) An impulse is then transmitted to the atrioventricular bundle, bundle branches, Purkinje fibers, and right papillary muscle (QRS complex). (5) The impulse moves to the contractile fibers of the ventricle. (6) Ventricular contraction begins. Adapted from OpenStax (2018).

frequency (VLF; 0–0.04 Hz), *low frequency* (LF; 0.04–0.15 Hz), and *high frequency* (HF; 0.15–0.40 Hz). The VLF band has been theorized to reflect vasomotor tone of thermoregulation and dynamics of hormonal systems, although its origins remain speculative (Kamath et al., 2012). Thus, in the present investigation the VLF band was interpreted as spectral noise. The LF band is primarily reflective of sympathetic neural oscillations, whereas the HF band represents vagal modulation or PNS activity (Kamath et al., 2012). The LF/HF ratio is thought to represent sympathovagal influences on HR (Malik et al., 1996), with higher values representing predominant sympathetic activity and lower values representing predominant parasympathetic activity (Malik et al., 1996).

Two of the most common algorithms used for analysing frequency domain variables are the fast Fourier transform (FFT) and coarse-graining spectral analysis

(CGSA). FFT is a nonparametric method that transforms R-R intervals into frequency bands represented by Hertz (Hz), a process that is similar to decomposing a song into the fundamental notes (Sztajzel, 2004). CGSA provides a more precise analysis (i.e., clearer peaks in the power spectrum) by dividing the total spectral power (TP; variance of the signal) into non-harmonic and harmonic components before estimating the frequency bands (Yamamoto & Hughson, 1991). In CGSA, the LF and HF bands again represent sympathetic and vagal contributions to HR modulation, respectively, and the LF/HF ratio represents sympathovagal influences (Aubert, Seps, & Beckers, 2003).

2.3.2 Demographics. Participants completed a demographic questionnaire enquiring about prior experience with yoga, age, sex, height, weight, student status, marital status, ethnicity, and if their biological sex is female, date of last menstrual cycle. As menstrual cycle influences autonomic function, women should ideally be tested in the early follicular phase of the menstrual cycle if not on hormonal contraceptives, or during the low hormone phase if on contraception (P. S. Mckinley et al., 2009).

2.4 Measures of Psychological Function

The **Beck Depression Inventory–Second edition** (BDI-II; Beck, Steer, Ball, & Ranieri, 1996) is a 21-item self-report measure that assesses the severity of cognitive, affective, and neurovegetative symptoms of depression. Participants respond by indicating the degree to which each item accurately represents the severity of the symptom over the past 2 weeks on a scale from 0 (*absence of symptom*) to 3 (*severe level of symptom*). Higher scores indicate greater depressive symptoms. The BDI-II demonstrated excellent internal consistency at pre-test ($\alpha = .89$) and post-test ($\alpha = .81$) in the present investigation.

The **Positive and Negative Affect Schedule** (PANAS; Watson, Clark, & Tellegen, 1988) is a 20-item self-report measure that assesses positive and negative affect. The items are arranged in two subscales. The positive affect (PA) subscale includes items such as “inspired”, whereas the negative affect (NA) subscale includes items such as “jittery”. The state version of this scale will be used in the present study, with participants reporting how they feel “right now, that is, at the present moment.” Participants respond using a 5-point scale that ranges from 1 (*very slightly or none at all*) to 5 (*extremely*), with higher scores indicating greater positive or negative affect. The PANAS demonstrated excellent internal consistency for the negative affect subscale at pre-test ($\alpha = .86$) and post-test ($\alpha = .95$), as well as for the positive affect subscale at pre-test ($\alpha = .85$) and post-test ($\alpha = .91$) in the present investigation.

The **State-Trait Anxiety Inventory** (STAI; Spielberger & Gorsuch, 1983) is a 40-item self-report measure that assesses state and trait anxiety symptoms. The items are divided into two subscales. The state subscale instructs participants to report how they feel at the present moment and it includes items such as “I am worried”. Participants respond to the state subscale on a scale from 1 (*not at all*) to 4 (*very much so*). The trait subscale instructs participants to report how they generally feel, and it includes items such as “I worry too much over something that doesn’t really matter.” Participants respond to the trait subscale on a scale from 1 (*almost never*) to 4 (*almost always*). Higher scores indicate greater anxiety symptoms. The STAI state subscale demonstrated excellent internal consistency at pre-test ($\alpha = .93$) and post-test ($\alpha = .91$) in the present investigation. The STAI trait subscale also demonstrated excellent internal consistency at pre-test ($\alpha = .94$) and post-test ($\alpha = .94$) in the present investigation.

The **Rosenberg Self-Esteem Scale** (RSES; Rosenberg, 1965) is a 10-item self-report measure that assesses trait self-esteem. Items include, "On the whole I am satisfied with myself" and are scored on a 4-point scale ranging from 1 (*strongly agree*) to 4 (*strongly disagree*). Higher scores indicate greater trait self-esteem. The RSES demonstrated excellent internal consistency at pre-test (α = .89) and post-test (α = .92) in the present investigation.

The **State Self-Esteem Scale** (SSES; Heatherton & Polivy, 1991) is a 20-item self-report measure that assesses state self-esteem. The items comprise three subscales: social, performance, and appearance esteem. The social subscale includes items such as, "I feel inferior to others at this moment." The performance subscale includes items such as, "I feel confident about my abilities." The appearance subscale includes items such as, "I feel unattractive." Participants respond using a 5-point scale ranging from 1 (*not at all*) to 5 (*extremely*), with higher scores indicating greater state self-esteem. The SSES demonstrated excellent internal consistency at pre-test (α = .92) and post-test (α = .93) in the present investigation.

The **Perceived Stress Scale** (PSS; Cohen, Kamarck, & Mermelstein, 1983) is a 10-item self-report measure that assesses current levels of experienced stress including how unpredictable, uncontrollable, and overloaded an individual's life feels at the time of responding. Items include, "In the last month, how often have you found that you could not cope with all the things that you had to do?" and are scored on a 5-point scale ranging from 0 (*never*) to 4 (*very often*). Higher scores indicate greater levels of perceived stress. The PSS demonstrated good internal consistency at pre-test (α = .78) and excellent internal consistency at post-test (α = .90) in the present investigation.

The **Inventory of Interpersonal Problems** (IIP; Horowitz, Alden, Wiggins, & Pincus, 2000) is a 32-item self-report measure that assesses interpersonal difficulties. The items comprise eight subscales that correspond to the eight octants of the interpersonal circumplex (Kiesler, 1996): domineering/controlling (DC), vindictive/self-centered (VS), cold/distant (CD, socially inhibited (SI), non-assertive (NA), overly accommodating (OA), self-sacrificing (SS), and intrusive/needy (IN). Items such as, "I am affected by another person's misery too much" are rated from 0 (*not at all*) to 4 (*extremely*). Higher scores indicate greater interpersonal problems. The sum of IIP subscales demonstrated excellent internal consistency at pre-test (α = .92) and post-test (α = .90) in the present investigation. The IIP subscales demonstrated good to excellent internal consistency at pre-test (α = .70–.91) and post-test (α = .75–.88).

It is argued that assessment of complex constructs, such as mindfulness, at the facet level is essential for clarifying their relationships with other variables (Schneider, Hough, & Dunnette, 1996; G. T. Smith et al., 2007; G. T. Smith, Fischer, & Fister, 2003; G. T. Smith & McCarthy, 1995). Therefore, the **Five Facet Mindfulness Questionnaire** (FFMQ; Baer et al., 2008) was used in the present study. The FFMQ is a 39-item self-report measure that assesses five different facets of mindfulness.

The first facet is *observing* (noticing) internal and external experiences, and this subscale includes items such as, "When I am walking, I deliberately notice the sensations of my body moving." The second facet is *describing* (labelling) internal experiences such as thoughts and feelings, and this subscale includes items such as, "I am good at finding the words to describe my feelings." The third facet is *acting with awareness* in present-moment activities, and it includes items such as, "It seems I am 'running on automatic' without much awareness of what I’m doing” (reverse coded). The fourth facet is *non-judging* of internal experiences, and this subscale includes items such as, “I criticize myself for having irrational or inappropriate emotions,” (reverse coded). The fifth facet is *non-reactivity* to inner experiences and this subscale includes items such as, “I perceive my feeling and emotions without having to react to them”. Items are rated on a scale from 1 (*never or very rarely true*) to 5 (*always or always true*) with higher scores meaning higher mindfulness. In the present investigation, the observing and acting with awareness subscales demonstrated good to excellent internal consistency at pre-test ($\alpha = .79–.80$) and post-test ($\alpha = .77–.75$). However, the describing, non-judging, and non-reactivity subscales did not demonstrate adequate internal consistency ($\alpha s < 0$) and thus they were not interpreted.

CHAPTER III.

RESULTS

3.1 Data Preparation

Statistical analyses were performed using IBM SPSS Statistics. Beat-to-beat HR data were pre-processed using customized software (CVMonitor Version 5 –Peter Picton, CCPL, Toronto Ontario 2016) and Kubios HRV analysis software (Tarvainen, Niskanen, Lipponen, Ranta-Aho, & Karjalainen, 2014). Ensemble averages (the average representation of the cardiac cycle dependent on the detection of R peaks) were taken from a minimum of 400 beats (McGowan et al., 2009). Artifacts (i.e., anomalies such as incorrect automatic placement/detection of R peak, timing inconsistencies) were edited and replaced either manually or by linear interpolation from neighbouring cardiac cycles. Only tracings with <5% corrected beats were accepted (McGowan et al., 2009); thus, five of the 24 participants were excluded from the final HRV analyses. R-R intervals were assessed via FFT and CGSA. A missing values analysis was conducted on all study variables and missing values were imputed via multiple imputation. Statistical assumptions then were assessed, and standardized residual change scores were calculated for later analyses.

3.1.1 Missing data. Following the recommendations of Schafer and Graham (2002), missing data analyses were conducted for all variables with missing values. Overall, six cases were missing data; one participant was lost to follow-up and five cases were identified as having >5% corrected heart beats during HRV pre-processing. The total percentage of missing values in the dataset was 4.93%, and these data were missing completely at random (MCAR) as indicated by Little's MCAR test, χ^2 (243) = 85.29, p =

1.00. Thus, multiple imputation (MI) was employed and pooled data were analyzed. MI is a robust parametric method for estimating missing values under MCAR conditions and is considered to be the gold standard for handling missing data (Rubin, 1987; Schafer & Graham, 2002; Tabachnick & Fidell, 2007). MI predicts each participant's missing values based on their observed values, with arbitrary noise added to preserve variability in the imputed dataset (Schafer & Graham, 2002).

3.1.2 Assessing statistical assumptions for parametric tests. The following assumptions were assessed before parametric analyses were conducted and interpreted: normality, the absence of outliers and influential observations, linearity, and homogeneity of variance. Normality was assessed via graphical (visual inspection of residual plots) and statistical (skewness and kurtosis tests) methods. Skew and kurtosis values were divided by their respective standard errors to compute standardized scores, and distributions with values greater than |3.29| were considered non-normal at an alpha level of .001 (Tabachnick & Fidell, 2007). The following scales showed graphically and statistically positively skewed distributions: PANAS negative subscale at baseline and post-test (z = 3.23 and 4.90, respectively), and IIP vindictive/self-centered subscale at baseline (z = 3.84).

Histograms, Q-Q plots, and boxplots were inspected visually for univariate outliers. Given the small sample size, standardized residuals greater than |2.5| and Cook's distance values >1 were considered as potential univariate outliers and influential observations, respectively (Pituch, Stevens, & Whittaker, 2007). Using these guidelines, the following outliers were identified graphically: BDI at baseline (n = 1), PANAS negative subscale at post-test (n = 1), IIP vindictive/self-centered and non-assertive subscales at baseline (*n* = 2), FFT-LF/HF at baseline (*n* = 1), CGSA-LF at post-test (*n* = 1), CGSA-HF at post-test (*n* = 1), and CGSA-LF/HF at post-test (*n* = 1). The eight univariate outliers were reduced via winsorization, by replacing outliers with the next non-outlying value (Gwet & Rivest, 1992). Re-examination of skew and kurtosis values indicated that all variables were now in the acceptable range. No influential observations were identified. Evaluation of Mahalanobis distance indicated that there were no highly influential multivariate outliers. Finally, visual inspection of residual plots revealed that the assumptions of linearity and homogeneity of variance were met (Tabachnick & Fidell, 2007).

3.1.3 Calculating residualized change scores. To measure differences across two time points, researchers often employ the difference score method (also known as delta) whereby pre-test values are subtracted from post-test values; however, because psychological tests are not perfectly reliable and values at baseline are influenced by the magnitude of possible change (e.g., as mentioned, physiological variables are highly responsive to training effects), it has been argued that analysis of the resulting difference scores may lead to spurious conclusions related to random measurement error rather than true change (Cronbach & Furby, 1970). Further, differences may diminish over time in the absence of effects in key predictors, a phenomenon known as regression toward the mean (Castro-Schilo & Grimm, 2018). The present investigation utilized the residualized change approach to calculate standardized values that then were used to calculate the correlation of change between two variables. The residualized change approach was chosen over the difference score approach to increase reliability and preserve variance, a method viewed as superior to the difference score approach (Bernstein, Scoboria, Desjarlais, & Soucie, 2018; Veldman & Brophy, 1974). See Appendix J for a more detailed explanation of the reason the residualized change score approach is superior to the difference score approach.

To understand residualized change scores and their subsequent correlations, it is important to first discuss the conceptual basis for these calculations as doing so will lend support for interpretation. The first step in calculating residuals for change scores is to conduct multiple regression analyses for each outcome variable, in which post-test scores are regressed onto pre-test scores, and their standardized residuals are saved for subsequent analysis. The resulting standardized residuals or residualized change scores isolate the variance in post-test scores related to changes in the variable(s) of interest, which produces less biased estimates than the difference score method (Castro-Schilo & Grimm, 2018). In other words, the standardized residuals provide estimates of change after accounting for individual differences at baseline.

In sum, calculating standardized residuals allows for closer examination of the magnitude of change that may be accounted for by the intervention such that residuals close to zero represent little to no change. This allows the researcher to more precisely conclude that the left-over (residual) change is, at least in part, due to the intervention rather than random error.

3.1.4 Post-hoc power analysis. Post-hoc power analyses were conducted using G*Power 3.1.92 ($\alpha = .05$, $\beta = .80$; Erdfelder, Faul, & Buchner, 1996). It was determined that the sample size in the present study ($N = 24$) was sufficiently powered to detect statistical significance in standardized effects that are at least $d = 0.53$ and in bivariate correlations that are at least $r = 0.49$. However, there is much controversy surrounding the utility of significance testing (McLean & Ernest, 1998; Tabachnick & Fidell, 2007), and many methodologists in the behavioural sciences urge the concurrent use of effect sizes and their associated confidence intervals when evaluating differences, as *p*-values alone do not provide information about the magnitude of effects, or whether the results warrant replication due to their practical importance (J. Cohen, 1988; Keppel & Wickens, 2004; McLean & Ernest, 1998; Tabachnick & Fidell, 2007; Wilkinson & Task Force on Statistical Inference, 1999). Thus, given the relative infancy of the present field of research, as well as potential clinical implications of the results, standardized effect size estimates ≥ 0.20 and correlations ≥ 0.30 were considered meaningful (Kazdin, 2003; Keppel & Wickens, 2004). In other words, effects that fail to reach significance but show effect sizes above this cut-off may require larger samples to detect statistical significance. Indeed, a post hoc power analysis revealed that effects of this magnitude require a sample size of at least 67 to reach statistical significance. Therefore, the present study was underpowered due to the small sample size, limiting the significance of some of the statistical comparisons conducted.

3.2 Primary Analyses

Based on the results of previous empirical research, directional hypotheses were explored in the present investigation. Two-way repeated measures analyses of variance (ANOVAs) and bivariate correlations between residualized change scores were calculated to assess the effectiveness of the 6-week Ashtanga yoga intervention. Given the sex differences known to contribute to depression (Whisman & Richardson, 2015), anxiety (Hill, Musso, Jones, Pella, & Gouvier, 2013), perceived stress (Baum & Grunberg, 1991), self-esteem (Block & Robins, 1993), interpersonal problems (Gurtman

& Lee, 2009), heart rate variability (Koenig & Thayer, 2016), and blood pressure (Myers, Robinson, Riley III, & Sheffield, 2001), ANOVAs were conducted with sex as the between-subjects factor (male, female) and time as the within-subjects factor (pre-test, post-test). Significant findings were followed by simple effects analyses to examine sex differences at pre- and post-test, as well as to examine separately how males and females responded to the Ashtanga yoga intervention over time. In the multiple regression analyses used to calculate residualized change scores, sex was added as a covariate to control for its effects on the subsequent correlations.

One-tailed tests were examined due to a priori directional hypotheses that participants would improve in outcome variables over time. Because SPSS does not calculate one-tailed repeated measures ANOVAs, *p*-values were manually adjusted for the main effects of time by dividing them in half (Cuttler, 2014), and effects were considered statistically significant if $p \leq .05$. Effect sizes also were assessed to determine clinical utility of the intervention and relationships between variables. Cohen's *d* effect sizes were calculated using a Microsoft Excel-based program (Coe, n.d.). See Appendix K for intercorrelations between all psychological and physiological outcome variables.

3.3 Testing Hypothesis 1

To test the hypothesis that participants would show significant improvements in psychological functioning from baseline to the end of the Ashtanga yoga intervention, two-way repeated measures ANOVAs were conducted with sex as the between-subjects factor (male, female) and time as the within-subjects factor (pre-test, post-test). See Table 2 descriptive statistics and effect size estimates.

Table 2. *Descriptive Statistics and Effect Size Estimates for Psychological Variables (N=24)*

	Mean (*SD*)				Effect Size	
	Pre-intervention		Post-intervention		*d* [90% CI]	
BDI	9.85	(8.34)	4.12	(3.74)	**.89**	[0.28, 1.46]
PANAS						
Negative	14.25	(5.69)	12.19	(3.13)	**.45**	[–0.13, 1.01]
Positive	29.50	(9.82)	30.52	(8.78)	.11	[–0.67, 0.46]
STAI						
State	37.21	(10.61)	32.23	(6.80)	**.56**	[–0.03, 1.12]
Trait	41.71	(11.42)	38.23	(10.37)	**.32**	[–0.26, 0.88]
PSS	18.46	(6.23)	15.57	(6.37)	**.46**	[–0.12, 1.02]
SSES	74.58	(11.78)	77.14	(11.87)	**.22**	[–0.78, 0.36]
RSES	31.25	(4.49)	31.30	(4.95)	.01	[–0.58, 0.56]
IIP	38.71	(19.49)	35.20	(16.45)	.19	[–0.38, 0.76]
Overly Controlling	2.42	(2.50)	2.78	(2.67)	.14	[–0.70, 0.43]
Vindictive/Self-centered	2.96	(4.16)	1.96	(2.25)	**.30**	[–0.28, 0.86]
Cold/Distant	4.21	(4.06)	3.27	(2.43)	.12	[–0.45, 0.68]
Socially Inhibited	4.79	(3.82)	4.35	(3.58)	.19	[–0.38, 0.75]
Non-assertive	6.71	(3.92)	6.52	(3.26)	.05	[–0.51, 0.62]
Overly accommodating	7.38	(4.06)	5.79	(3.65)	**.41**	[–0.17, 0.97]
Self-sacrificing	6.00	(3.88)	5.86	(3.64)	.04	[–0.53, 0.60]
Intrusive/Needy	4.25	(4.06)	4.68	(3.88)	.11	[–0.67, 0.46]
FFMQ						
Observing	3.35	(0.64)	3.38	(0.55)	.05	[–0.62, 0.52]
Acting with Awareness	2.97	(0.68)	2.79	(0.53)	**.30**	[–0.27, 0.87]

Note. Cohen's *d*s were calculated for the effect of time; estimates ≥ 0.20 appear in bold. BDI = Beck Depression Inventory; PANAS = Positive-Negative Affect Schedule; STAI = State-Trait Anxiety Inventory; SSES = State Self-Esteem Scale; RSES = Rosenberg Self-Esteem Scale; PSS = Perceived Stress Scale; IIP = Inventory of Interpersonal Problems; FFMQ = Five Facet Mindfulness Questionnaire.

As hypothesized, following 6 weeks of twice weekly Ashtanga yoga, improvements in depressive and anxiety symptoms, negative affect, self-esteem, perceived stress, interpersonal functioning, and mindfulness were observed.

3.3.1 Internalizing symptoms. The ANOVA for depressive symptoms (BDI) yielded a main effect of time, $F(1,22) = 5.00$, $p = .019$, indicating that overall levels of depression significantly decreased from pre-test to post-test (Figure 8). There was no significant main effect of sex, $F(1,22) = 0.05$, $p = .826$, or a time × sex interaction, $F(1,22) = 0.44$, $p = .517$.

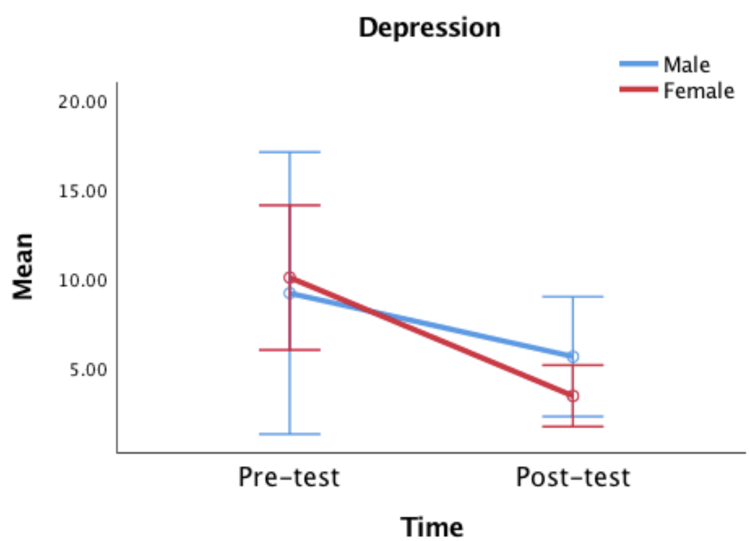

Figure 8. Changes in pre-to-post BDI scores. Error bars depict 95% CI.

The ANOVA for the negative affect subscale of the PANAS did not yield a main effect of time, $F(1,22) = 0.91$, $p = .175$, a main effect of sex, $F(1,22) = 1.13$, $p = .299$, or a time × sex interaction, $F(1,22) = 0.71$, $p = .424$. However, effect size estimates ($d = .45$, 90% CI = –0.13 to 1.01) suggest that participants experienced meaningful decreases in negative affect, with effects appearing to be present primarily in females (Figure 9). The

ANOVA for the positive affect subscale of the PANAS did not yield a main effect of time, $F(1,22) = 0.00$, $p = .477$, a main effect of sex, $F(1,22) = 0.40$, $p = .536$, or a time × sex interaction, $F(1,22) = 0.40$, $p = .484$, indicating that participants did not experience significant changes in positive affect from pre-test to post-test.

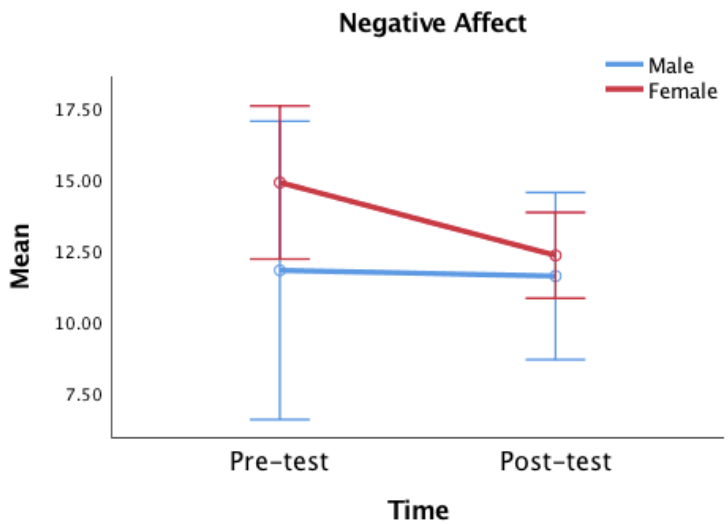

Figure 9. Changes in pre-to-post PANAS negative subscale scores. Error bars depict 95% CI.

There was a main effect of time for the state anxiety subscale of the STAI, $F(1,22) = 5.01$, $p = .018$, indicating that participants experienced significant decreases in state anxiety from pre-test to post-test (Figure 10). The ANOVA also yielded a main effect of sex, $F(1,22) = 4.62$, $p = .043$, such that females experienced less state anxiety across both timepoints compared to males. These main effects were not qualified by a significant interaction $F(1,22) = 2.24$, $p = .229$. The ANOVA for the trait anxiety subscale of the STAI did not yield a main effect of time, $F(1,22) = 2.72$, $p = .057$, a main effect of sex, $F(1,22) = 2.57$, $p = .124$, or a time × sex interaction, $F(1,22) = 0.00$, $p =$

.288. However, effect size estimates (d = .32, 90% CI = –0.26 to 0.88) suggest that participants experienced meaningful decreases in trait anxiety from pre-test to post-test, with effects appearing to be driven by males (Figure 11). This indicates that participants may generally feel less anxious after engaging in 6 weeks of twice weekly Ashtanga yoga.

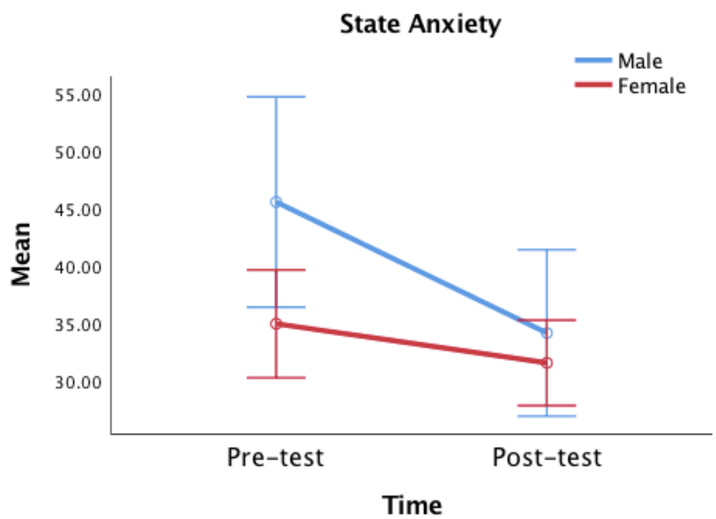

Figure 10. Changes in pre-to-post STAI state subscale scores. Error bars depict 95% CI.

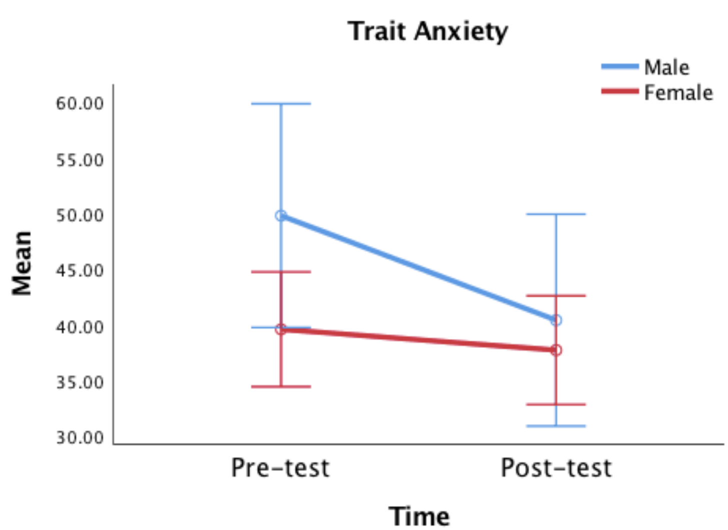

Figure 11. Changes in pre-to-post RSES scores. Error bars depict 95% CI.

3.3.2 Perceived stress. The ANOVA for perceived stress (PSS) did not yield a main effect of time, $F(1,22) = 0.26$, $p = .310$, a main effect of sex, $F(1,22) = 2.25$, $p = .148$, or a time × sex interaction, $F(1,22) = 1.69$, $p = .169$. However, effect size estimates ($d = .46$, 90% CI = –0.12 to 1.02) suggest that participants experienced meaningful decreases in perceived stress from pre-test to post-test, with effects appearing to be driven primarily by females (Figure 12). In other words, female participants may have felt less stressed after engaging in the Ashtanga yoga intervention.

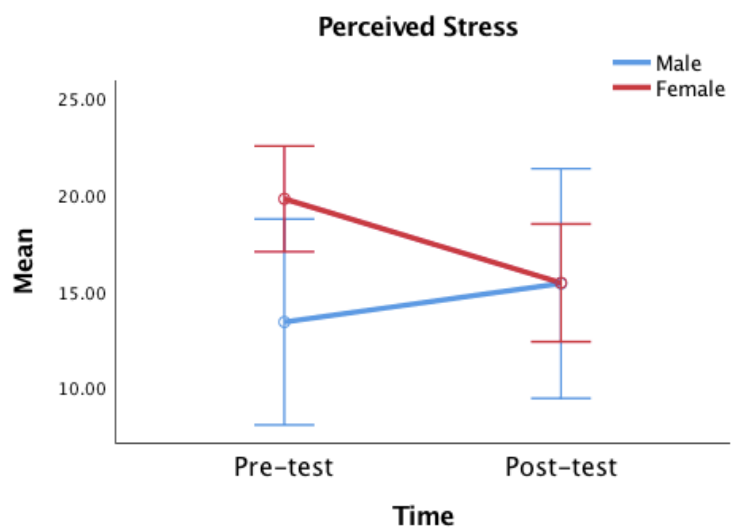

Figure 12. Changes in pre-to-post PSS scores. Error bars depict 95% CI.

3.3.3 Self-esteem. The ANOVA for state self-esteem (SSES) did not yield a main effect of time, $F(1,22) = 1.41$, $p = .124$, a main effect of sex, $F(1,22) = 2.38$, $p = .137$, or a sex × time interaction, $F(1,22) = 0.98$, $p = .363$. However, effect size estimates ($d = .56$, 90% CI = –0.03 to 1.12) suggest that participants experienced meaningful increases in state self-esteem, with effects appearing to be present primarily in males (Figure 13).

This indicates that male participants may have experienced an increase in global state self-esteem following the Ashtanga yoga intervention. The ANOVA for trait self-esteem (RSES) did not reveal a main effect of time, $F(1,22) = 0.12$, $p = .366$, main effect of sex $F(1,22) = 2.33$, $p = .141$, or a time × sex interaction, $F(1,22) = 0.26$, $p = .590$, indicating that participants did not experience significant increases in their general feelings of self-esteem.

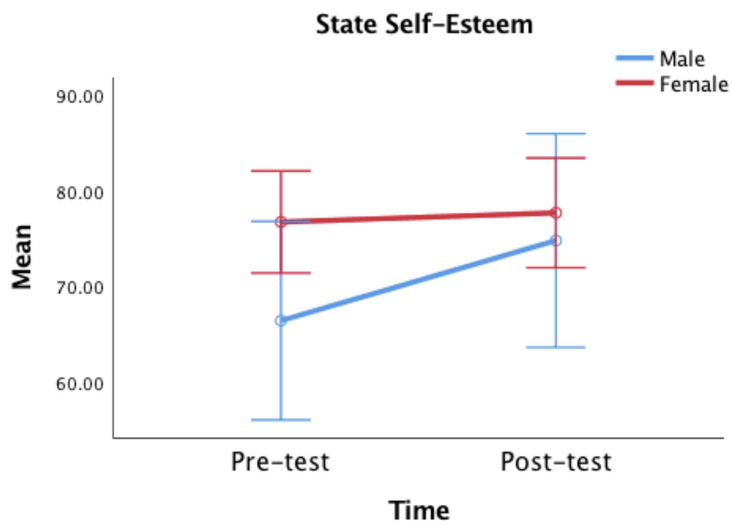

Figure 13. Changes in pre-to-post SSES scores. Error bars depict 95% CI.

3.3.4 Interpersonal functioning. The ANOVA for overall interpersonal problems (IIP) did not yield a main effect of time, $F(1,22) = 0.19$, $p = .334$, a main effect of sex, $F(1,22) = 22.5$, $p = .148$, or a time × sex interaction, $F(1,22) = 0.74$, $p = .359$. Similarly, the ANOVAs for IIP subscales also did not yield main effects or a significant time × sex interaction (all *p*s > .069). However, effect size estimates ($d = .30$; 90% CI = –0.28 to 0.86) suggest that participants experienced meaningful improvements in interpersonal problems related to being vindictive or self-centered from pre-test to post-test (Figure 14a). Effect sizes also suggest that participants experienced meaningful improvements in problems related to being overly accommodating (*d* = .41, 90% CI = –0.17 to 0.97; Figure 14b). In other words, participants may have felt less vindictive or self-centered, and overly accommodating after engaging in 6 weeks of twice weekly Ashtanga yoga.

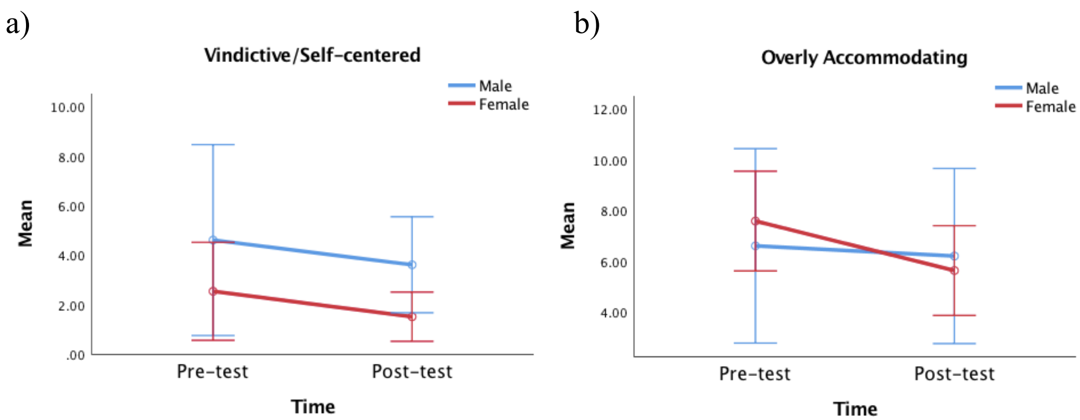

Figure 14. Changes in pre-to-post IIP scores for (a) the vindictive/self-centered subscale and (b) the overly accommodating subscale. Error bars depict 95% CI.

3.3.5 Mindfulness. The ANOVA for the observing subscale of the FFMQ did not yield a main effect of time, $F(1,22) = 0.04$, $p = .423$, a main effect of sex, $F(1,22) = 0.13$, $p = .722$, or a time × sex interaction, $F(1,22) = 0.01$, $p = .979$. Similarly, the ANOVA for the acting with awareness subscale of the FFMQ did not yield a main effect of time, $F(1,22) = 1.30$, $p = .134$, a main effect of sex, $F(1,22) = 0.54$, $p = .468$, or a time × sex interaction, $F(1,22) = 0.23$, $p = .965$. Effect size estimates (*d* = .30, 90% CI = –0.27 to 0.87) suggest that participants experienced meaningful decreases in the acting with awareness facet of mindfulness from pre-test to post-test (Figure 15). This indicates that participants may have felt as though they were acting with less awareness following the Ashtanga yoga intervention.

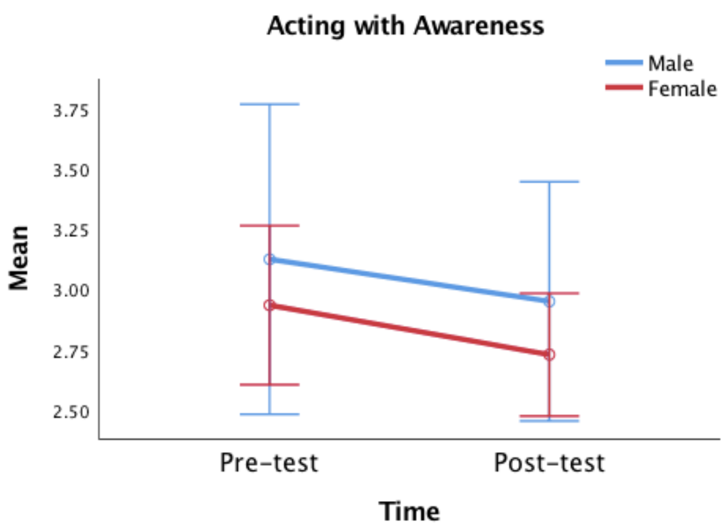

Figure 15. Changes in pre-to-post FFMQ scores for the acting with awareness subscale. Error bars depict 95% CI.

3.4 Testing Hypothesis 2

To test the hypothesis that participants would experience improvements in HRV indices reflective of increased parasympathetic activity (i.e., increased standard deviation of normal R-R intervals, increased high frequency power [vagal tone]) and improved autonomic balance (i.e., improved low frequency/high frequency ratio) after participating in the Ashtanga yoga intervention, two-way repeated measures ANOVAs were conducted, with sex as the between-subjects factor (male, female) and time as the within-subjects factor (pre-test, post-test). See Table 3 for descriptive statistics and effect size estimates.

As hypothesized, following 6 weeks of twice weekly Ashtanga yoga, clinically significant improvements in autonomic modulation were observed, but changes in parasympathetic activity did not reach significance. Note that a post-hoc power analysis revealed that a total sample of 52 participants would be required to detect small effects in parasympathetic activity (d = .20) with 80% power using a repeated measures ANOVA at the 5% alpha level.

Table 3. *Descriptive Statistics and Effect Sizes for Physiological Variables (N=24)*

	Mean (*SD*)				Effect Size	
	Pre-intervention		Post-intervention		*d* [90% CI]	
RMSSD	71.73	(31.17)	77.61	(35.96)	.17	[–1.12, 0.03]
FFT-TP (ms^2)	8221.92	(6565.32)	7265.58	(4853.52)	.17	[–0.40, 0.73]
CGSA-TP (ms^2)	964.05	(929.79)	800.21	(630.21)	**.21**	[–0.37, 0.77]
FFT-LF (ms^2)	2075.98	(1562.15)	2173.85	(1612.30)	.06	[–0.63, 0.51]
CGSA-LF (ms^2)	449.77	(633.79)	366.95	(446.20)	.15	[–0.42, 0.71]
FFT-HF (ms^2)	2102.54	(1603.61)	2456.85	(2024.84)	.19	[–0.76, 0.38]
CGSA-HF (ms^2)	514.28	(473.55)	438.11	(289.00)	.19	[–0.38, 0.76]
FFT-LF/HF (ms^2)	1.28	(1.08)	1.31	(1.11)	.03	[–0.59, 0.54]
CGSA-LF/HF (ms^2)	1.13	(1.54)	1.09	(1.21)	.03	[–0.53, 0.60]
SBP (mmHg)	103.82	(7.98)	104.40	(8.53)	.07	[–0.63, 0.50]
DBP (mmHg)	61.86	(6.77)	58.88	(7.09)	**.43**	[–0.15, 0.99]

Note. Cohen's *d*s were calculated for the effect of time; estimates ≥ 0.20 appear in bold. RMSSD = root mean square of R-R interval differences; FFT = fast Fourier transform; CGSA = coarse-graining spectral analysis; LF = low frequency (sympathetic activity); HF = high frequency (parasympathetic activity); TP = total power; SBP = systolic blood pressure; DBP = diastolic blood pressure. The LF/HF ratio represents autonomic modulation, with lower values indicating parasympathetic predominance.

3.4.1 Sympathetic nervous system activity. The ANOVA for the low frequency component of HR utilizing the fast Fourier transformation (FFT-LF) did not yield a main effect of time, $F(1,22) = 0.02$, $p = .452$, indicating that there were no significant changes in sympathetic contributions to HR from pre-test to post-test. The ANOVA did, however, yield a main effect of sex, $F(1,22) = 10.50$, $p = .004$, such that females showed less LF spectral power or sympathetic activity across both timepoints compared to males (Figure 16a). This effect was not qualified by its interaction with time, $F(1,22) = 0.37$, $p = .504$.

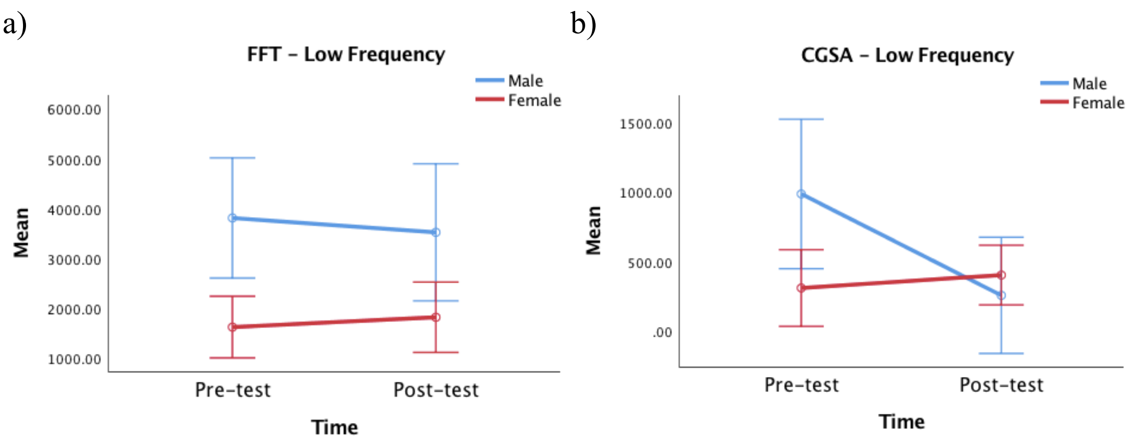

Figure 16. Changes in pre-to-post LF values, representing sympathetic contributions to heart rate. (a) FFT = fast Fourier transform. (b) CGSA = coarse-graining spectral analysis. Note that CGSA provides a more precise analysis (i.e., clearer peaks in the power spectrum) of heart rate variability than fast Fourier transform by dividing the total spectral power (variance of the signal) into non-harmonic and harmonic components before estimating the frequency bands, thus reducing noise. Error bars depict 95% CI.

When utilizing coarse-graining spectral analysis (CGSA-LF), a more precise analysis of sympathetic contributions to HR, the ANOVA yielded a main effect of time, $F(1,22) = 8.73$, $p = .004$. This indicates that there were indeed significant changes in sympathetic activity from pre-test to post-test (Figure 16b). Although the ANOVA did not yield a main effect of sex, $F(1,22) = 1.27$, $p = .271$, its interaction with time was significant, $F(1,22) = 13.08$, $p = .001$, indicating that the effect of the Ashtanga yoga intervention on sympathetic activity differed depending on sex. Simple effects analyses revealed that this difference occurred at baseline, $t(22) = 2.32$, $p = .020$, with females ($M = 308.51$, $SD = 553.25$) showing less sympathetic drive than males ($M = 986.55$, $SD = 690.97$). When examining changes from pre- to post-test, only males showed significant reductions in sympathetic contributions to HR, $t(22) = 2.97$, $p = .041$, whereas females showed no change, $t(18) = 0.95$, $p = .341$.

3.4.2 Parasympathetic nervous system activity. The ANOVA for the high frequency component of HR utilizing FFT (FFT-HF) did not yield a main effect of time, $F(1,22) = 0.49$, $p = .247$, a main effect of sex, $F(1,22) = 0.61$, $p = .444$, or a time × sex interaction, $F(1,22) = 0.32$, $p = .606$. When utilizing CGSA-HF, a more precise analysis of the parasympathetic contributions to HR, the ANOVA also did not yield a main effect of time, $F(1,22) = 0.82$, $p = .188$, a main effect of sex, $F(1,22) = 0.61$, $p = .444$, or a time × sex interaction, $F(1,22) = 0.32$, $p = .606$. These findings indicate that there were no significant changes in parasympathetic activity following the Ashtanga yoga intervention.

3.4.3 Autonomic modulation. The ANOVA for the low frequency to high frequency ratio utilizing FFT (FFT-LF/HF) did not yield a main effect of time, $F(1,22) = 0.34$, $p = .286$, indicating that there were no significant changes in autonomic modulation from pre-test to post-test. The ANOVA did, however, yield a main effect of sex, $F(1,22) = 9.49$, $p = .006$, such that females showed a smaller LF/HF ratio across both timepoints compared to males (Figure 17a). This indicates that on average, female participants had greater parasympathetic engagement over time than did males. The main effect of sex was not qualified by its interaction with time, $F(1,22) = 0.37$, $p = .498$.

The ANOVA for the low frequency to high frequency ratio utilizing CGSA (CGSA-LF/HF) also did not yield a main effect of time, $F(1,22) = 2.11$, $p = .084$. However, the ANOVA yielded a main effect of sex, $F(1,22) = 4.65$, $p = .043$, and this effect was qualified by its interaction with time, $F(1,22) = 0.37$, $p = .040$ (Figure 17b). This finding indicates that the effect of the Ashtanga yoga intervention on autonomic modulation differed depending on sex. Simple effects analyses revealed that this difference occurred at baseline, $t(22) = 2.77$, $p = .006$, with females ($M = 0.74$, $SD = 1.00$) showing a smaller LF/HF ratio than males ($M = 2.63$, $SD = 2.37$). When examining changes from pre- to post-test, only males showed significant reductions in the LF/HF ratio, $t(4) = 2.97$, $p = .003$, whereas females showed no change, $t(18) = 0.95$, $p = .342$. Taken together with the findings in CGSA-LF changes, this reduction in the CGSA-LF/HF ratio indicates that male participants experienced a significant shift of autonomic balance toward parasympathetic predominance following the Ashtanga yoga intervention.

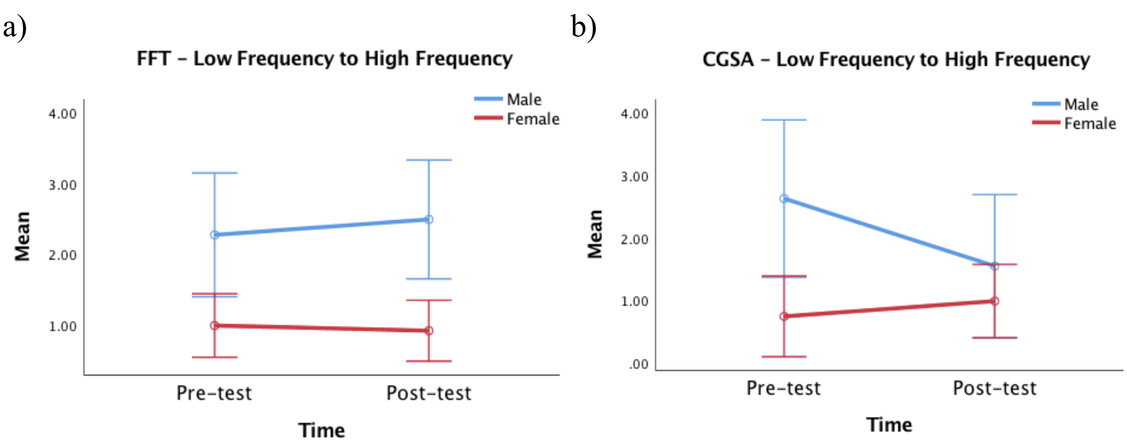

Figure 17. Changes in pre-to-post HF/LF ratio values, representing autonomic modulation. Higher ratio values indicate sympathetic predominance, and lower values indicate parasympathetic predominance. (a) FFT = fast Fourier transform. (b) CGSA = coarse-graining spectral analysis. Note that CGSA provides a more precise analysis (i.e., clearer peaks in the power spectrum) of heart rate variability than fast Fourier transform by dividing the total spectral power (variance of the signal) into non-harmonic and harmonic components before estimating the frequency bands, thus reducing noise. Error bars depict 95% CI.

3.4.4 Overall heart rate variability. The ANOVA for the root mean square of R-R interval differences (RMSSD) did not yield a main effect of time, $F(1,22) = 0.10$, $p = .377$, a main effect of sex, $F(1,22) = 1.09$, $p = .308$, or a time × sex interaction, $F(1,22) = 0.75$, $p = .350$, indicating that there were no significant changes in overall HRV from pre-test to post-test.

3.5 Testing Hypothesis 3

To test the hypothesis that HRV indices reflective of increased parasympathetic activity (i.e., increased standard deviation of normal R-R intervals, increased high frequency power [vagal tone]) and improved autonomic modulation (i.e., improved low frequency/high frequency ratio) would be correlated with improvements in psychological functioning following the Ashtanga yoga intervention, one-tailed bivariate correlations were conducted on residualized change scores. See Tables 4 to 6 for correlations between residualized change scores. Note that the presented correlations *only* provide an index of the magnitude of the association between two variables (see Appendix L for graphical representations of positive, negative, and null correlations using the present data to aid interpretation of the findings). A positive correlation indicates that a large change in one variable is associated with a large change in the other variable. A negative correlation indicates that a large change in one variable is associated with a small change in the other variable. For the direction of the correlations, refer to the means in Tables 2 and 3. As hypothesized, following 6 weeks of Ashtanga yoga, improvements in autonomic function were significantly associated with improvements in psychological variables.

3.5.1 Internalizing symptoms. The correlation between the standardized residuals for BDI and CGSA-LF/HF illustrates that the change in depression from pre-to-post, and the change in autonomic balance from pre-to-post are negatively associated ($r = –.36$; Table 4). Based on an examination of the means (Tables 2 and 3), BDI scores declined and CGSA-LF/HF decreased over time. This indicates that on average as parasympathetic predominance increased during the Ashtanga yoga intervention, participants reported feeling less depressed over time.

Pre-to-post changes in positive affect (PANAS-Pos) were positively associated with changes in resting systolic blood pressure (SBP; $r = .36$; Table 4). Based on an examination of the means (Tables 2 and 3), scores on PANAS-Pos increased and SBP increased over time. This indicates that on average as resting SBP increased, participants also reported experiencing more positive affect or emotion over time.

Pre-to-post changes in state and trait anxiety (STAI-State, STAI-Trait) were negatively correlated with changes parasympathetic activity (FFT-HF; $r = –.33$ and $r = –.35$, respectively; Table 4). Based on an examination of the means (Tables 2 and 3), scores on STAI-State and STAI-Trait decreased and FFT-HF increased over time. This indicates that on average as parasympathetic activity increased, participants reported lower state and trait anxiety over time.

Table 4. *Correlations Between Internalizing Symptoms and Variables Associated with ANS[a] Function*

Variable	RMSSD	FFT-LF	CGSA-LF	FFT-HF	CGSA-HF	FFT-LF/HF	CGSA-LF/HF
BDI	–.01	.27	–.04	–.20	–.09	–.07	**–.36***
PANAS							
Neg	–.23	–.19	–.17	–.25	–.08	–.19	–.24
Pos	–.09	–.20	.17	.00	.20	–.11	.15
STAI							
State	–.26	–.23	.01	**–.33**	–.09	–.13	.07
Trait	–.22	.07	.19	**–.35***	.31	.13	–.10
PSS	.03	.15	.19	–.03	.20	.00	–.01

Note. Correlations are between residualized change scores for each variable; correlations >.30 appear in bold. BDI = Beck Depression Inventory; PANAS = Positive-Negative Affect Schedule; STAI = State-Trait Anxiety Inventory; PSS = Perceived Stress Scale; RMSSD = root mean square of R-R interval differences; FFT = fast Fourier transform; CGSA = coarse-graining spectral analysis; LF = low frequency (sympathetic activity); HF = high frequency (parasympathetic activity). LF/HF ratio represents autonomic modulation, with lower values indicating parasympathetic predominance.
[a] ANS = autonomic nervous system
*$p < .05$

3.5.2 Self-esteem. The correlation between the standardized residuals for state self-esteem (SSES; Table 5) and parasympathetic activity (CGSA-HF) illustrates that the change in overall state self-esteem from pre-to-post, and the change in parasympathetic activity ($r = –.37$) from pre-to-post are negatively associated. Based on an examination of the means (Tables 2 and 3), scores on SSES increased, and CGSA-HF increased over time. This indicates that on average as vagal tone improved, participants reported higher state self-esteem over time.

Table 5. *Correlations Between Self-esteem and Variables Associated with ANS[a] Function*

Variable	RMSSD	FFT-LF	CGSA-LF	FFT-HF	CGSA-HF	FFT-LF/HF	CGSA-LF/HF
SSES	.15	–.15	–.27	.20	**–.37***	–.05	.12
RSES	.07	–.12	–.03	.23	–.23	.00	.15

Note. Correlations are between residualized change scores for each variable; correlations >.30 appear in bold. SSES = State Self-Esteem Scale; RSES = Rosenberg Self-Esteem Scale; RMSSD = root mean square of R-R interval differences; FFT = fast Fourier transform; CGSA = coarse-graining spectral analysis; LF = low frequency (sympathetic activity); HF = high frequency (parasympathetic activity). LF/HF ratio represents autonomic modulation, with lower values indicating parasympathetic predominance.

[a] ANS = autonomic nervous system

*$p < .05$

3.5.3 Interpersonal functioning. The correlations between the standardized residuals for overall interpersonal problems (IIP Total; Table 6), parasympathetic activity (CGSA-HF), and autonomic modulation (FFT-LF/HF) illustrates that the change in interpersonal functioning from pre-to-post and the change in parasympathetic activity (r = .30), and autonomic balance (r = .33) are positively associated. Based on an examination of the means (Tables 2 and 3), IIP Total decreased, CGSA-HF decreased, and FFT-LF/HF increased over time. This indicates that on average as sympathetic predominance increased from pre-to-post, participants also reported lower interpersonal problems over time.

Specifically, changes in OC were positively associated with changes in FFT-LF/HF (r = .36), indicating that on average as sympathetic drive increased, participants reported feeling more overly controlling over time. Changes in CD were positively associated with changes in CGSA-HF (r = .38), indicating that on average as parasympathetic activity decreased, participants reported feeling less interpersonally cold or distant from others over time. Changes in SI were positively associated with changes in FFT-LF (r = .34), CGSA-HF (r = .45), and FFT-LF/HF (r = .31), indicating that on average as vagal tone decreased, and sympathetic predominance increased, participants reported feeling less socially inhibited over time. Changes in OA were negatively associated with changes in CGSA-LF/HF (r = –.41), indicating that on average as parasympathetic predominance increased, participants reported feeling less overly accommodating over time. Finally, changes in IN were negatively associated with changes in CGSA-LF/HF (r = –.41), indicating that as parasympathetic drive increased, participants reported feeling more intrusive or needy over time.

Table 6. *Correlations Between Interpersonal Functioning and Variables Associated with ANS[a] Function*

Variable	RMSSD	FFT-LF	CGSA-LF	FFT-HF	CGSA-HF	FFT-LF/HF	CGSA-LF/HF
IIP Total	.01	.22	.01	–.08	**.30**	**.33**	–.28
OC	.26	.06	.12	.03	–.12	**.36***	.03
SC	–.17	.12	–.10	–.08	.26	.11	–.16
CD	–.06	–.01	–.07	–.04	**.38***	.06	–.10
SI	.06	**.34**	.01	.04	**.45***	**.31**	–.16
NA	.10	.10	–.24	–.04	.27	.07	–.16
OA	–.10	.14	–.15	–.04	.13	.12	**–.41***
SS	.06	.13	.25	–.04	–.15	.10	–.09
IN	.11	.08	.20	.10	.17	.07	**–.41***

Note. Correlations are between residualized change scores for each variable; correlations >.30 appear in bold. IIP = Inventory of Interpersonal Problems; OC = overly controlling; SC = self-centered; CD = cold/distant; SI = socially inhibited; NA = non-assertive; OA = overly accommodating; SS = self-sacrificing; IN = intrusive/needy; RMSSD = root mean square of R-R interval differences; FFT = fast Fourier transform; CGSA = coarse-graining spectral analysis; LF = low frequency (sympathetic activity); HF = high frequency (parasympathetic activity). LF/HF ratio represents autonomic modulation, with lower values indicating parasympathetic predominance.
[a] ANS = autonomic nervous system
*$p < .05$

3.5.4 Mindfulness. The correlations between the standardized residuals for the observing facet of mindfulness (FFMQ-O; Table 7) and parasympathetic activity (CGSA-HF) illustrate that the changes in parasympathetic activity from pre-to-post and the changes in the observing facet of mindfulness from pre-to-post are negatively associated (r = –.43). Based on an examination of the means, scores on FFMQ-O increased and CGSA-HF decreased over time. This indicates that on average as vagal tone decreased, participants also reported higher observing over time.

Pre-to-post changes in the acting with awareness facet of mindfulness (FFMQ-AA; Table 7) and autonomic modulation (CGSA-LF/HF) were negatively associated (r = –.46). Based on an examination of the means, scores on FFMQ-AA decreased and CGSA-LF/HF decreased throughout the Ashtanga yoga intervention. This indicates that on average, as vagal tone increased, participants also reported feeling declines in acting with awareness.

Table 7. *Correlations Between Mindfulness and Variables Associated with ANS*[a] *Function*

Variable	RMSSD	FFT-LF	CGSA-LF	FFT-HF	CGSA-HF	FFT-LF/HF	CGSA-LF/HF
FFMQ							
O	–.23	–.04	–.21	.26	**–.43***	.05	–.13
AA	.00	.19	–.01	–.13	.21	.18	**–.46***

Note. Correlations are between residualized change scores for each variable; correlations >.30 appear in bold. FFMQ = Five Facet Mindfulness Questionnaire; O = observing; AA = acting with awareness; RMSSD = root mean square of R-R interval differences; FFT = fast Fourier transform; CGSA = coarse-graining spectral analysis; LF = low frequency (sympathetic activity); HF = high frequency (parasympathetic activity). LF/HF ratio represents autonomic modulation, with lower values indicating parasympathetic predominance.
[a] ANS = autonomic nervous system
*p < .05, **p < .01

3.6 Supplementary Analyses

Supplementary analyses were conducted on resting BP to investigate whether significant changes in this variable were observed following the Ashtanga yoga intervention. The ANOVA for resting systolic blood pressure (SBP) did not yield a main effect of time, $F(1,22) = 0.54$, $p = .235$, a main effect of sex, $F(1,22) = 3.82$, $p = .064$, or a time × sex interaction, $F(1,22) = 0.56$, $p = .453$. Similarly, the ANOVA for resting diastolic blood pressure (DBP) did not yield a main effect of time, $F(1,22) = 1.53$, $p = .116$, a main effect of sex, $F(1,22) = 0.55$, $p = .467$, or a time × sex interaction, $F(1,22) = 1.80$, $p = .187$. However, effect size estimates ($d = .43$, 90% CI = –0.15, 0.99) suggest that participants showed meaningful reductions in resting DBP from pre-test to post-test, with effects appearing to be present only in females (Figure 18).

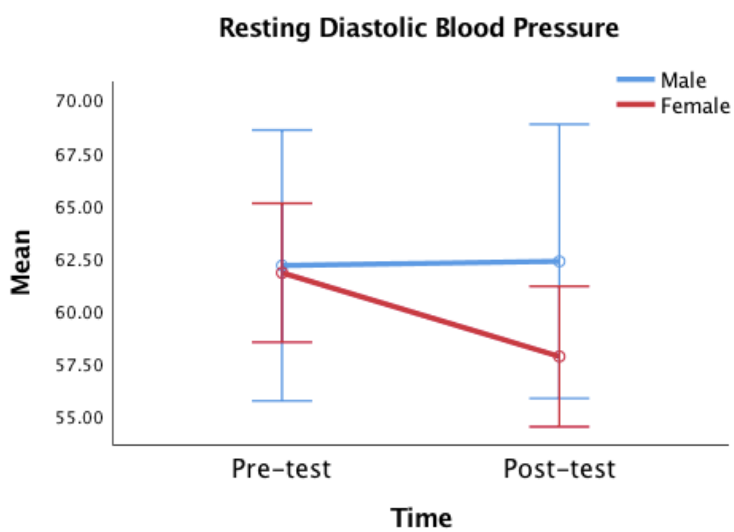

Figure 18. Changes in pre-to-post DBP values. Error bars depict 95% CI.

CHAPTER IV.

DISCUSSION AND CONCLUSIONS

4.1 General Discussion

The recent widespread appeal of yoga in general and scientific communities, as well as its increasing use as a complementary therapy, highlights the importance of empirically assessing the ways in which yoga produces improvements in psychological well-being and physical health. A major limitation in existing yoga research, however, is the wide variability in what is considered "yoga" in published studies. This makes the interpretation of results difficult and interferes with advancing our knowledge of yoga's mechanisms of action. Because of its standardized practice, Ashtanga yoga addresses this limitation, making it suitable as a stable independent variable for empirical investigation. Ashtanga also is the only known traditional style of yoga that is practiced under the tristana, a method that integrates physical exercise, controlled breathing, and gaze or a point of visual focus. When combined, these three components induce a state of focused attention or the first stage of meditation. Finally, Ashtanga yoga concomitantly integrates unique aerobic and isometric resistance properties that mimic high intensity interval training (HIIT). These aerobic and resistance exercise practices affect autonomic nervous system (ANS) modulation by activating the parasympathetic nervous system (PNS), producing a sense of calm, and attenuating the sympathetic nervous system (SNS), commonly known as the fight-or-flight (stress) response (Cannon, 1932).

Therefore, the aim of the present study was to explore the potential association between the ANS and the previously reported beneficial effects of Ashtanga yoga on psychological well-being (Jarry et al., 2017; Jarry et al., under revision). The focus of the investigation was to test three hypotheses in an intensive, single group, pre-/post-design study on a sample of healthy young adults. It was hypothesized that following the Ashtanga yoga intervention (1) participants would show significant improvements in psychological well-being; (2) participants would show improvements in heart rate variability (HRV) indices reflective of increased parasympathetic activity and improved autonomic balance; and (3) changes in these HRV indices would be correlated with improvements in psychological well-being.

4.2 Discussion of Hypothesis 1 Findings

In accordance with the hypothesis that **participants would show improvements in psychological functioning from baseline to the end of an Ashtanga yoga intervention**, statistically (p values $\leq .05$) and meaningful (effect sizes $> .20$) improvements in depressive and anxiety symptoms, negative affect, self-esteem, perceived stress, interpersonal functioning, and mindfulness were observed. This is consistent with previous findings, which showed marked improvements in the same outcome variables following 9 weeks of Ashtanga yoga (Jarry et al., 2017; Jarry et al., under revision), as well as those of studies that have examined the effects of various styles of Hatha yoga on depression and anxiety (Cramer, Lauche, et al., 2013; Hofmann, Andreoli, Carpenter, & Curtiss, 2016). Although meta-analyses have yet to examine yoga's effectiveness for enhancing negative affect, self-esteem, perceived stress, and interpersonal functioning, the present study adds to the growing body of literature supporting improvements in these psychological variables (e.g., Kovačič & Kovačič, 2011; Mackenzie et al., 2014; Riley & Park, 2015).

4.2.1 Internalizing symptoms and self-esteem. The marked improvement in depressive symptoms following the Ashtanga yoga intervention are consistent with the growing body of literature supporting yoga's large antidepressant effects. That the large effects for depression have held across three of our Ashtanga intervention studies using healthy mixed-sex samples, one of which was medication naïve, suggests that Ashtanga yoga should be considered as a primary treatment for depression in the medical community.

The finding that female participants experienced less state anxiety across time points than did males directly contradicts a recent psychometric evaluation of the State-Trait Anxiety Inventory (STAI; Hill et al., 2013), which found that females scored higher than males on state anxiety, whereas males scored higher than females on trait anxiety. Only male participants were found to decrease in state anxiety, which is not surprising given that they began the study with higher state anxiety than did females. However, because the pattern of our results appears similar for trait anxiety, it is likely that state changes are due to the intervention rather than regression to the mean. This is consistent with Hill et al.'s (2013) findings that young adult males typically score higher than young adult females on trait anxiety. Thus, had the intervention not occurred, it would be expected that males would have continued to experience higher levels of general anxiety than females.

The unexpected findings that decreases in state self-esteem appear to be primarily driven by males may be due to individual differences at baseline. Consistent with expected norms (Hill et al., 2013), male participants began the intervention feeling more anxious than female participants, and they appeared to feel less anxious at the end of the study as a result of the intervention. Thus, improvements in this group may be partly attributed to their baseline elevation when compared to females, which allowed for more room to improve.

4.2.2 Perceived stress and interpersonal functioning. Sex differences also were demonstrated in perceived stress, with improvements appearing to be driven by females. This finding is consistent with studies investigating the psychometric properties of the Perceived Stress Scale (PSS), which found that females typically score higher on this measure than do males (Gurtman & Lee, 2009; Lee, 2012). Given that participants experienced meaningful improvements in interpersonal functioning related to being less overly accommodating, it may be that this alleviated feelings of stress within the female group. This interpretation corresponds to the literature on personality disorders, with females showing higher prevalence rates of dependent and borderline personality disorders (Lynam & Widiger, 2007), suggesting that females experience more distress related to these constructs than do males. According to some researchers (e.g., Hilsenroth, Menaker, Peters, & Pincus, 2007; Pincus & Gurtman, 1995), these disorders fall in the Friendly–Submissive area of the interpersonal circumplex, the exact quadrant that the overly accommodating subscale of the IIP measures. Thus, it may be that some of the stress female participants were experiencing was related to interpersonal factors. However, further investigation is needed to elucidate this relationship. Taken together with the demonstrated sex differences in anxiety, it is highly recommended that research on psychological outcome variables in mixed-sex samples be explored separately for effects of sex.

4.2.3 Mindfulness. The acting with awareness facet of mindfulness decreased throughout the intervention, rather than increased as was expected. Given that this subscale taps into the construct of focused attention, the only facet of mindfulness that is taught in Ashtanga yoga through the tristana (Baer, Smith, Hopkins, Krietemeyer, & Toney, 2006) this was a surprising finding. Although speculative, it may be that this was the first time many of the participants had been trained to engage in focused attention and they experienced difficulty focusing their wandering thoughts, making their distractibility more salient. This may have become more noticeable to them through the intervention, resulting in them reporting now being more aware of their difficulty in remaining focussed on their general daily activities and behaviour.

Another speculation for this inconsistent finding may be related to the nature of the study design. Post-testing was completed at the end of the school semester and most of the participants were university or college students. It is possible that distractibility and difficulty remaining focused in daily activity was a function of the fatigue that often accompanies the end of a school term.

4.3 Discussion of Hypothesis 2 Findings

In accordance with the hypothesis that **participants would experience improvements in heart rate variability indices reflective of increased parasympathetic activity and improved autonomic modulation following an Ashtanga yoga intervention**, improvements in autonomic modulation, but not in overall HRV or parasympathetic activity were observed.

4.3.1 Autonomic function. Although there were no significant changes in parasympathetic activity across both sexes, possibly due to the underpowered statistical analyses, the demonstrated improvements in autonomic balance found in the male participants supports the prediction that Ashtanga yoga is associated with improved autonomic function. Across time points, females showed lower overall sympathetic engagement and greater overall vagal activity than males, and this finding is consistent with the literature on sex differences in healthy HRV (Koenig & Thayer, 2016). Note that vagal activity or vagal tone refers to an increase in parasympathetic (inhibitory) activity. Surprisingly, changes in autonomic modulation were seen only in males, with a significant shift from sympathoexcitation toward parasympathetic predominance. This is sex difference is likely due to the lower overall sympathetic activity seen in females, which is consistent with the heart rate variability literature. Further, given that this was a particularly healthy sample with frequency domain indices of HRV falling well below normal values (Malik et al., 1996), there was very little for improvement in this outcome variable.

4.4 Discussion of Hypothesis 3 Findings

In accordance with the final hypothesis that **HRV indices reflective of increased PNS activity and improved autonomic modulation will be correlated with improvements in psychological functioning from baseline to the end of an Ashtanga yoga intervention**, correlations between improvements in overall autonomic function (PNS, SNS, and autonomic balance) and improvements in psychological outcome variables were observed.

4.4.1 Physiological correlates of internalizing symptoms and self-esteem. With respect to depression, state and trait anxiety, and state self-esteem, it appears as though these variables are related to parasympathetic predominance or improved vagal tone. This is consistent with the natural function of the PNS such that higher parasympathetic or vagal activity induces the feeling of calmness. Thus, it makes sense that this increased feeling of calmness would be related to improved mood and confidence in one's own worth, as well as less anxiety, which is increased in an excitatory state.

In contrast, increased resting systolic blood pressure (SBP) was associated with increased positive affect. Similar to the relationship between internalizing symptoms and the PNS, this finding is consistent with the natural function of arterial blood pressure (BP). First, as discussed in the introduction, the SNS is the primary regulator of BP, and one underlying response to stress is that the SNS releases the vasoconstricting hormone/neurotransmitter norepinephrine, which increases SBP. Second, Watson et al. (1988) define the positive affect scale of the PANAS as representing both state and trait mood factors, with state positive affect reflecting feelings of enthusiasm, engagement, and alertness and trait positive affect reflecting the dominant personality factor of extraversion. In terms of the state component of positive affect, it makes sense that increased SBP would be related to increased alertness given that higher SBP is a result of sympathoexcitation.

In terms of the trait component of positive affect, however, it appears as though, as discussed below, participants felt an increased sense of agency or control within their interactions with others and felt and more outgoing following the Ashtanga yoga intervention. At the same time, they experienced higher sympathetic engagement, increased SBP, and thus more positive affect over time. This may explain why effects for positive affect did not reach significance, as changes in SBP were negligible. Therefore, it is likely that a longer intervention is needed to detect chronic effects in SBP and positive affect.

Not only is this interpretation consistent with the literature on training effects in SBP (Millar et al., 2008; O'Sullivan & Bell, 2000; Pescatello et al., 2015), but also it is consistent with previous findings showing meaningful, but not statistically significant improvements in positive affect following a 9 week Ashtanga yoga intervention, with the authors concluding that a longer intervention may be needed to detect statistically significant changes in this variable (Jarry et al., 2017). Similarly, this interpretation is consistent with a more recent randomized controlled trial which showed that participants in the Ashtanga yoga group experienced modest improvements in positive affect following a 9 week Ashtanga yoga intervention, whereas those in the control group showed declines in this variable (Jarry et al., under revision). In other words, in a healthy individual, chronic training adaptations in SBP may require longer programs, and if positive affect is correlated with this variable, it is likely that improvements in this variable also may require longer training programs to detect statistical effects.

4.4.2 Physiological correlates of interpersonal functioning. The present study provides compelling evidence to support the notion that interpersonal functioning is directly affected by autonomic modulation. In a sample of young, healthy, and highly educated individuals, it appears as though sympathoexcitation predicts improved overall interpersonal functioning, with higher sympathetic engagement related to increased feelings of agency or control in interpersonal interactions (overly controlling) and decreased feelings of social anxiety, timidity, or embarrassment in the presence of other people (socially inhibited). In contrast, higher parasympathetic engagement predicts increased feelings of friendliness and sociability (cold/distant) and a decreased need for social approval and reassurance from other people (overly accommodating).

These findings suggest that increases in sympathetic activity may not necessarily be bad. In other words, together with the parasympathetic changes noted above, it appears as though Ashtanga yoga substantially improves autonomic modulation such that the PNS and SNS become more efficient at adapting to contextual situations. For example, the PNS may be more effectively regulating mood, anxiety, and self-esteem, which then increases feelings of friendliness and decreases the need for social approval. At the same time, the SNS may be working more efficiently to improve interpersonal interactions by increasing dominance and decreasing timidity when needed in social contexts.

4.4.3 Physiological correlates of mindfulness. Findings suggest that increases in vagal tone predict decreases in the acting with awareness facet of mindfulness. Despite reporting decreases on this mindfulness subscale, which indicates that they were feeling more distracted and less focused, participants experienced parasympathetic predominance or a more internally restful state. As previously discussed, it may be that as participants were becoming more aware of the construct of mindfulness through their practice, they became more aware of their distractibility. Thus, despite feeling an increased sense of calmness, they also were experiencing greater insight into their distractibility. This means that, like positive affect, other positive emotion states such as acting with awareness may require more time before improvements can be detected.

In contrast, decreases in vagal tone predicted higher levels of the observing facet of mindfulness. Item level analysis of the FFMQ observing facet indicates that sympathetic activity is related to increased attention to, and observation of, internal stimuli such as noticing how food and drink affects thoughts, bodily sensations, and emotions. These findings are consistent with the nature of the SNS such that increases in its activity result in a heightened state of awareness, important in the fight-or-flight response.

4.5 Discussion of Supplementary Analyses

Unexpected supplementary findings revealed that participants showed meaningful reductions in diastolic blood pressure (DBP), but not systolic blood pressure (SBP), following the intervention. Although this effect appeared to be stronger in female participants when compared to males, findings should be interpreted with caution as the sample was primarily comprised of females and the error bars were large.

As previously discussed, one unique aspect of Ashtanga yoga is that it is a combined aerobic and isometric resistance training program, and thus these DBP findings are consistent with a recent meta-analysis of exercise training effects on BP, which showed that DBP decreased (~2.2 mmHg) after combined endurance and isometric resistance training, whereas SBP was reduced only after separate training interventions (Cornelissen & Smart, 2013). Further, the DBP reductions found in the present study have profound implications for health in the general population. For example, a dated but large-scale longitudinal study conducted on men and women between the ages of 35–64 years found that reductions as small as 2 mmHg in the population distribution of DBP would result a 17% decrease in the prevalence of hypertension and a 6% decrease in the risk of coronary heart disease (Cook, Cohen, Hebert, Taylor, & Hennekens, 1995). Moreover, small elevations in DBP can significantly increase the risk of cardiovascular disease, especially for younger adults (Cook et al., 1995; Kannel, Gordon, & Schwartz, 1971). Thus, the DBP reductions found in our extremely healthy sample cannot be understated in terms of importance, and replication in a controlled trial is essential.

In addition, if sex differences are verifiable in a subsequent RCT, this finding also is of great importance to post-menopausal women, as BP greatly increases in this population and is largely unaffected by hormone replacement therapy (Miller et al., 1995; Pripp et al., 1999). Given the growing interest in yoga in general, the ease with which Ashtanga yoga postures can be modified to adjust for injuries and fitness level, and the documented safety by which individuals with chronic debilitating illnesses can practice yoga, these findings are potentially far-reaching in terms of public health and could support a new direction for complementary treatment of hypertension.

This is the first empirical finding to support Ashtanga yoga for decreasing blood pressure in a normotensive population and, as mentioned, replication in a randomized controlled design is warranted to further confirm this relationship. Further investigation into potential sex differences also may shed light on the mechanisms underlying known protective factors present in women against cardiovascular and renal diseases, thus providing new avenues for prevention and treatment (Kang & Miller, 2002).

4.6 Limitations and Future Considerations

The primary methodological limitation in the present investigation is related to the study design. A control group was not used as this was the first study to explore the potential relationship between autonomic function and the psychological benefits of Ashtanga yoga and thus feasibility needed to be determined. As such, the study was open to classic threats to internal validity. Control over extraneous factors, however, was maximized by several important design elements.

This study utilized a one group pre-/post-test design, which makes it vulnerable to threats of history such that changes in the outcome variables may be produced by events other than the Ashtanga yoga intervention. For example, many of the participants were college or university students, and post-testing was conducted at the end of the school term; related stress and/or fatigue may have influenced scores on outcome variables rather than intervention effects. Future research should consider assessing factors related to everyday life, such as productivity or fatigue, as well as qualitative analyses to investigate potential reasons behind quantitative findings.

The threat of maturation was reduced, at least in part, by restricting the intervention timeline from the 9 weeks utilized in our previous studies to 6 weeks. Threats of instrumentation or measurement devices changing systematically over time were addressed by maintaining rigorous testing standards. Attrition surprisingly was not an issue in the present study as only one participant was lost to post-testing, and potential differential attrition was addressed by multiply imputing missing values. Pre-test sensitization and biased assignment due to the nature of self-selection remain threats to internal validity that cannot be addressed until randomization procedures are used. Self-selection, however, contributed to external validity as the sample was representative of the population we sought to measure.

4.7 Summary of Conclusions

To conclude, the findings of the present investigation are multifarious and support feasibility of similar future studies. The improvements in psychological well-being, such as depressive and anxiety symptoms, perceived stress, self-esteem, and interpersonal functioning following the Ashtanga yoga intervention add to the body of yoga literature supporting improvements in these psychological variables. To date, this is the first known study to demonstrate that parasympathetic dominance predicts improvements in depression, anxiety, and state self-esteem. The present investigation also provides the first known empirical evidence for the physiological correlates of interpersonal functioning such that it is directly related to autonomic modulation. Further, demonstrated sex differences in several psychological outcome variables highlight the need for separately investigating effects when using mixed-sex samples in psychological studies.

With the exception of diastolic blood pressure, improvements in physiological outcome variables did not reach significance, and it is likely that a larger sample and a longer Ashtanga yoga intervention are needed to detect chronic effects of the training. However, several of the null findings can be explained by floor and ceiling effects that resulted from the very healthy sample of young adults. In other words, not only were most of the baseline psychological and physiological values within normal range, several of them were better than what would be expected in a normal population. As such, there was minimal room to move and thus detecting statistical changes post-intervention was limited. Decreases in DBP appeared in female participants only, and replication of this effect is needed before conclusions about Ashtanga's effectiveness for reducing blood pressure can be made. The direction of causality in all effects in the present study remain speculative and randomized controlled trials are needed to provide clarity.

Several physiological mechanisms of action have been proposed in the literature for yoga's related psychological improvements, and the present investigation successfully completed the first step in this line of inquiry by investigating whether direct relationships could be found between outcome variables. The next step is to conduct randomized controlled trials to confirm effects of the intervention, further disentangle causality, and explore effects in clinical populations. Taken together, the findings in the present investigation are consistent with proposed theories of the physiological mechanisms of change in the practice of yoga in general, and they provide the first empirically supported evidence for the association between ANS function and the reported effects of Ashtanga yoga specifically.

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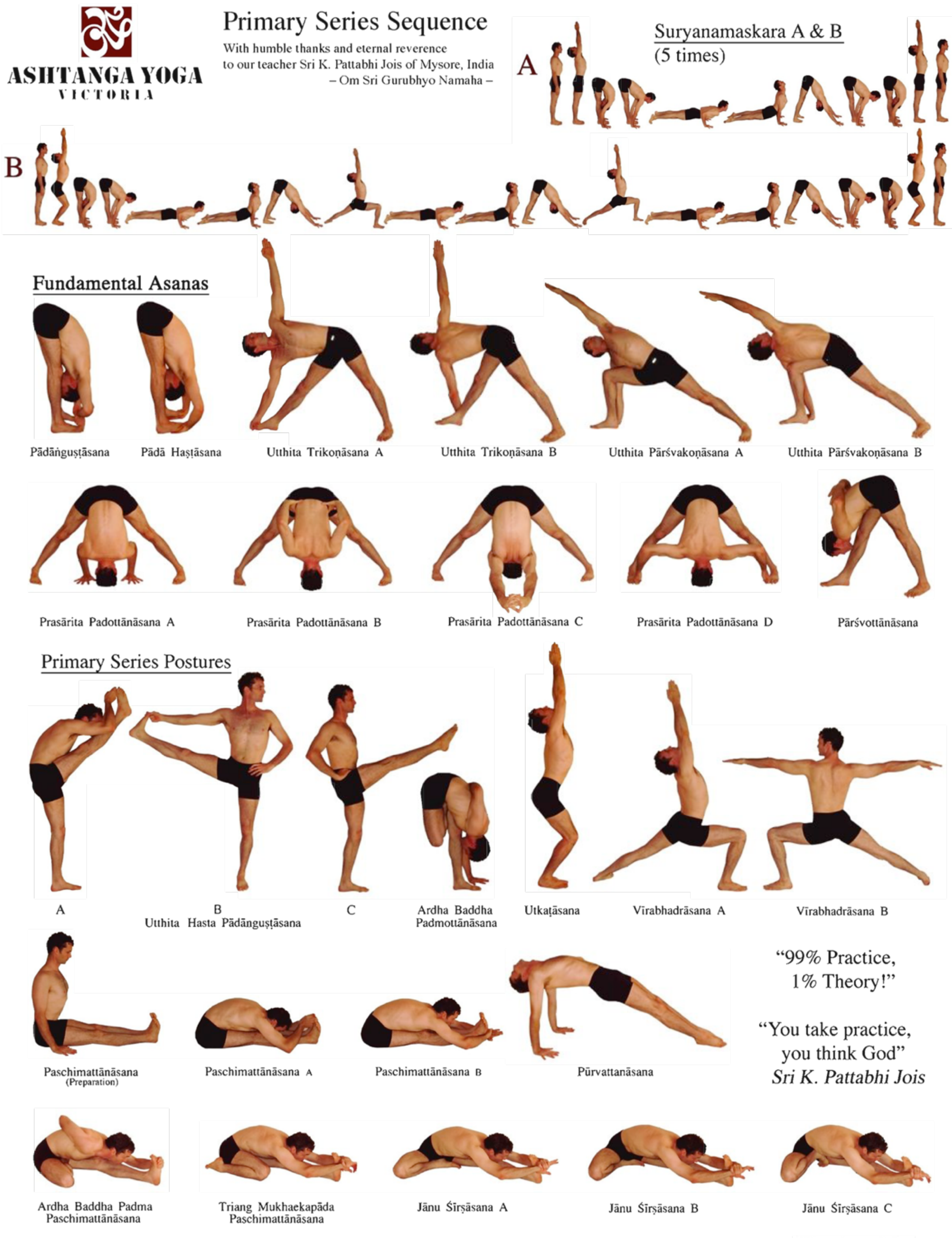
APPENDICES

Appendix A

Sample Ashtanga Yoga Poses



Appendix B

Recruitment Poster

FREE Ashtanga yoga classes!

Are you between the ages of 18–30?

You may be eligible to take part in a study investigating whether improvements in the autonomic nervous system are associated with changes in psychological well-being following a 6-week, twice weekly Ashtanga Yoga Programme. You will be offered a chance to win a 'Yoga Essentials Kit' worth $125 for participating.

CLASSES: Tuesdays & Thursdays, 5:00–6:15 p.m.
LOCATION: Windsor Jewish Community Centre (1641 Ouellette Ave)

Please contact Ashley at theyogastudy@uwindsor.ca or visit www.theyogastudy.com for more information.

Enroll now! Space is limited!

This research has been reviewed and received clearance from the University of Windsor Research Ethics Board.

University of Windsor

Appendix C

Physical Activity Readiness Questionnaire (PAR-Q+)

Do you currently take any birth control medications? YES ☐ NO ☐

If yes, please specify? ______________________________

Date of last menstrual cycle______________________________

2017 PAR-Q+

The Physical Activity Readiness Questionnaire for Everyone

The health benefits of regular physical activity are clear; more people should engage in physical activity every day of the week. Participating in physical activity is very safe for MOST people. This questionnaire will tell you whether it is necessary for you to seek further advice from your doctor OR a qualified exercise professional before becoming more physically active.

GENERAL HEALTH QUESTIONS

Please read the 7 questions below carefully and answer each one honestly: check YES or NO.	**YES**	**NO**
1) Has your doctor ever said that you have a heart condition ☐ OR high blood pressure ☐?	☐	☐
2) Do you feel pain in your chest at rest, during your daily activities of living, **OR** when you do physical activity?	☐	☐
3) Do you lose balance because of dizziness **OR** have you lost consciousness in the last 12 months? Please answer **NO** if your dizziness was associated with over-breathing (including during vigorous exercise).	☐	☐
4) Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)? **PLEASE LIST CONDITION(S) HERE:** ______________	☐	☐
5) Are you currently taking prescribed medications for a chronic medical condition? **PLEASE LIST CONDITION(S) AND MEDICATIONS HERE:** ______________	☐	☐
6) Do you currently have (or have had within the past 12 months) a bone, joint, or soft tissue (muscle, ligament, or tendon) problem that could be made worse by becoming more physically active? Please answer **NO** if you had a problem in the past, but it ***does not limit your current ability*** to be physically active. **PLEASE LIST CONDITION(S) HERE:** ______________	☐	☐
7) Has your doctor ever said that you should only do medically supervised physical activity?	☐	☐

If you answered NO to all of the questions above, you are cleared for physical activity.
Go to Page 4 to sign the PARTICIPANT DECLARATION. You do not need to complete Pages 2 and 3.

- Start becoming much more physically active – start slowly and build up gradually.
- Follow International Physical Activity Guidelines for your age (www.who.int/dietphysicalactivity/en/).
- You may take part in a health and fitness appraisal.
- If you are over the age of 45 yr and **NOT** accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.
- If you have any further questions, contact a qualified exercise professional.

If you answered YES to one or more of the questions above, COMPLETE PAGES 2 AND 3.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ at **www.eparmedx.com** before becoming more physically active.
- Your health changes - answer the questions on Pages 2 and 3 of this document and/or talk to your doctor or a qualified exercise professional before continuing with any physical activity program.

OSHF Ontario Society for Health and Fitness

01-01-2017

2017 PAR-Q+

FOLLOW-UP QUESTIONS ABOUT YOUR MEDICAL CONDITION(S)

1.	**Do you have Arthritis, Osteoporosis, or Back Problems?** If the above condition(s) is/are present, answer questions 1a-1c — If **NO** ☐ go to question 2	
1a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	**YES** ☐ **NO** ☐
1b.	Do you have joint problems causing pain, a recent fracture or fracture caused by osteoporosis or cancer, displaced vertebra (e.g., spondylolisthesis), and/or spondylolysis/pars defect (a crack in the bony ring on the back of the spinal column)?	**YES** ☐ **NO** ☐
1c.	Have you had steroid injections or taken steroid tablets regularly for more than 3 months?	**YES** ☐ **NO** ☐
2.	**Do you currently have Cancer of any kind?** If the above condition(s) is/are present, answer questions 2a-2b — If **NO** ☐ go to question 3	
2a.	Does your cancer diagnosis include any of the following types: lung/bronchogenic, multiple myeloma (cancer of plasma cells), head, and/or neck?	**YES** ☐ **NO** ☐
2b.	Are you currently receiving cancer therapy (such as chemotheraphy or radiotherapy)?	**YES** ☐ **NO** ☐
3.	**Do you have a Heart or Cardiovascular Condition?** *This includes Coronary Artery Disease, Heart Failure, Diagnosed Abnormality of Heart Rhythm* If the above condition(s) is/are present, answer questions 3a-3d — If **NO** ☐ go to question 4	
3a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	**YES** ☐ **NO** ☐
3b.	Do you have an irregular heart beat that requires medical management? (e.g., atrial fibrillation, premature ventricular contraction)	**YES** ☐ **NO** ☐
3c.	Do you have chronic heart failure?	**YES** ☐ **NO** ☐
3d.	Do you have diagnosed coronary artery (cardiovascular) disease and have not participated in regular physical activity in the last 2 months?	**YES** ☐ **NO** ☐
4.	**Do you have High Blood Pressure?** If the above condition(s) is/are present, answer questions 4a-4b — If **NO** ☐ go to question 5	
4a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	**YES** ☐ **NO** ☐
4b.	Do you have a resting blood pressure equal to or greater than 160/90 mmHg with or without medication? (Answer **YES** if you do not know your resting blood pressure)	**YES** ☐ **NO** ☐
5.	**Do you have any Metabolic Conditions?** *This includes Type 1 Diabetes, Type 2 Diabetes, Pre-Diabetes* If the above condition(s) is/are present, answer questions 5a-5e — If **NO** ☐ go to question 6	
5a.	Do you often have difficulty controlling your blood sugar levels with foods, medications, or other physician-prescribed therapies?	**YES** ☐ **NO** ☐
5b.	Do you often suffer from signs and symptoms of low blood sugar (hypoglycemia) following exercise and/or during activities of daily living? Signs of hypoglycemia may include shakiness, nervousness, unusual irritability, abnormal sweating, dizziness or light-headedness, mental confusion, difficulty speaking, weakness, or sleepiness.	**YES** ☐ **NO** ☐
5c.	Do you have any signs or symptoms of diabetes complications such as heart or vascular disease and/or complications affecting your eyes, kidneys, **OR** the sensation in your toes and feet?	**YES** ☐ **NO** ☐
5d.	Do you have other metabolic conditions (such as current pregnancy-related diabetes, chronic kidney disease, or liver problems)?	**YES** ☐ **NO** ☐
5e.	Are you planning to engage in what for you is unusually high (or vigorous) intensity exercise in the near future?	**YES** ☐ **NO** ☐

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6.	**Do you have any Mental Health Problems or Learning Difficulties?** *This includes Alzheimer's, Dementia, Depression, Anxiety Disorder, Eating Disorder, Psychotic Disorder, Intellectual Disability, Down Syndrome* If the above condition(s) is/are present, answer questions 6a-6b — If **NO** ☐ go to question 7	
6a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	**YES** ☐ **NO** ☐
6b.	Do you have Down Syndrome **AND** back problems affecting nerves or muscles?	**YES** ☐ **NO** ☐
7.	**Do you have a Respiratory Disease?** *This includes Chronic Obstructive Pulmonary Disease, Asthma, Pulmonary High Blood Pressure* If the above condition(s) is/are present, answer questions 7a-7d — If **NO** ☐ go to question 8	
7a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	**YES** ☐ **NO** ☐
7b.	Has your doctor ever said your blood oxygen level is low at rest or during exercise and/or that you require supplemental oxygen therapy?	**YES** ☐ **NO** ☐
7c.	If asthmatic, do you currently have symptoms of chest tightness, wheezing, laboured breathing, consistent cough (more than 2 days/week), or have you used your rescue medication more than twice in the last week?	**YES** ☐ **NO** ☐
7d.	Has your doctor ever said you have high blood pressure in the blood vessels of your lungs?	**YES** ☐ **NO** ☐
8.	**Do you have a Spinal Cord Injury?** *This includes Tetraplegia and Paraplegia* If the above condition(s) is/are present, answer questions 8a-8c — If **NO** ☐ go to question 9	
8a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	**YES** ☐ **NO** ☐
8b.	Do you commonly exhibit low resting blood pressure significant enough to cause dizziness, light-headedness, and/or fainting?	**YES** ☐ **NO** ☐
8c.	Has your physician indicated that you exhibit sudden bouts of high blood pressure (known as Autonomic Dysreflexia)?	**YES** ☐ **NO** ☐
9.	**Have you had a Stroke?** *This includes Transient Ischemic Attack (TIA) or Cerebrovascular Event* If the above condition(s) is/are present, answer questions 9a-9c — If **NO** ☐ go to question 10	
9a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	**YES** ☐ **NO** ☐
9b.	Do you have any impairment in walking or mobility?	**YES** ☐ **NO** ☐
9c.	Have you experienced a stroke or impairment in nerves or muscles in the past 6 months?	**YES** ☐ **NO** ☐
10.	**Do you have any other medical condition not listed above or do you have two or more medical conditions?** If you have other medical conditions, answer questions 10a-10c — If **NO** ☐ read the Page 4 recommendations	
10a.	Have you experienced a blackout, fainted, or lost consciousness as a result of a head injury within the last 12 months **OR** have you had a diagnosed concussion within the last 12 months?	**YES** ☐ **NO** ☐
10b.	Do you have a medical condition that is not listed (such as epilepsy, neurological conditions, kidney problems)?	**YES** ☐ **NO** ☐
10c.	Do you currently live with two or more medical conditions?	**YES** ☐ **NO** ☐

PLEASE LIST YOUR MEDICAL CONDITION(S) AND ANY RELATED MEDICATIONS HERE: ______________________

GO to Page 4 for recommendations about your current medical condition(s) and sign the PARTICIPANT DECLARATION.

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If you answered NO to all of the follow-up questions about your medical condition, you are ready to become more physically active - sign the PARTICIPANT DECLARATION below:

- It is advised that you consult a qualified exercise professional to help you develop a safe and effective physical activity plan to meet your health needs.
- You are encouraged to start slowly and build up gradually - 20 to 60 minutes of low to moderate intensity exercise, 3-5 days per week including aerobic and muscle strengthening exercises.
- As you progress, you should aim to accumulate 150 minutes or more of moderate intensity physical activity per week.
- If you are over the age of 45 yr and **NOT** accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.

If you answered **YES** to **one or more of the follow-up questions** about your medical condition:

You should seek further information before becoming more physically active or engaging in a fitness appraisal. You should complete the specially designed online screening and exercise recommendations program - the **ePARmed-X+ at www.eparmedx.com** and/or visit a qualified exercise professional to work through the ePARmed-X+ and for further information.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ **at www.eparmedx.com** before becoming more physically active.
- Your health changes - talk to your doctor or qualified exercise professional before continuing with any physical activity program.

- You are encouraged to photocopy the PAR-Q+. You must use the entire questionnaire and NO changes are permitted.
- The authors, the PAR-Q+ Collaboration, partner organizations, and their agents assume no liability for persons who undertake physical activity and/or make use of the PAR-Q+ or ePARmed-X+. If in doubt after completing the questionnaire, consult your doctor prior to physical activity.

PARTICIPANT DECLARATION

- All persons who have completed the PAR-Q+ please read and sign the declaration below.
- If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that a Trustee (such as my employer, community/fitness centre, health care provider, or other designate) may retain a copy of this form for their records. In these instances, the Trustee will be required to adhere to local, national, and international guidelines regarding the storage of personal health information ensuring that the Trustee maintains the privacy of the information and does not misuse or wrongfully disclose such information.

NAME ______________________________ DATE ______________________________

SIGNATURE ______________________________ WITNESS ______________________________

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER ______________________________

For more information, please contact
www.eparmedx.com
Email: eparmedx@gmail.com

Citation for PAR-Q+
Warburton DER, Jamnik VK, Bredin SSD, and Gledhill N on behalf of the PAR-Q+ Collaboration. The Physical Activity Readiness Questionnaire for Everyone (PAR-Q+) and Electronic Physical Activity Readiness Medical Examination (ePARmed-X+). Health & Fitness Journal of Canada 4(2):3-23, 2011.

The PAR-Q+ was created using the evidence-based AGREE process (1) by the PAR-Q+ Collaboration chaired by Dr. Darren E. R. Warburton with Dr. Norman Gledhill, Dr. Veronica Jamnik, and Dr. Donald C. McKenzie (2). Production of this document has been made possible through financial contributions from the Public Health Agency of Canada and the BC Ministry of Health Services. The views expressed herein do not necessarily represent the views of the Public Health Agency of Canada or the BC Ministry of Health Services.

Key References

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OSHF
Ontario Society for Health and Fitness

01-01-2017

Appendix D

Ongoing Consent Form

ONGOING CONSENT FORM

Title of Study: **Improved Autonomic Function as a Physiological Mechanism Underlying the Reported Psychological Effects of Ashtanga Yoga: Feasibility and Preliminary Effectiveness Study**

1) Do you remember the purpose of the study?

2) Do you have any questions pertaining to the study?

3) Do you still consent to be in the study?

I understand that I am able to withdraw from the study at any time. Please accept my initials below as an indication of my ongoing consent to participate.

____

Participant Name

Date	Changes in Physical Activity	Changes in Medication	Changes in Diet	Participant Initials

Appendix E

Global Consent Form

CONSENT TO PARTICIPATE IN RESEARCH

Title of Study: **Improved Autonomic Function as a Physiological Mechanism Underlying the Reported Psychological Effects of Ashtanga Yoga: Feasibility and Preliminary Effectiveness Study**

You are asked to participate in a research study conducted by Ms. Ashley Howard from the Department of Psychology at the University of Windsor.

If you have any questions or concerns about the research, please feel free to contact the study investigator, Ashley Howard or her faculty supervisors, Dr. Josée Jarry or Dr. Cheri McGowan.

PURPOSE OF THE STUDY

The purpose of this study is to examine the relationship between your psychological well-being (how you feel) and your body's involuntary processes (e.g., heart rate, blood pressure) after a 15-hour Intensive Ashtanga yoga programme.

In order to participate in this study you must have a blood pressure lower than 135/85 mmHg, and you must be between 18–30 years old. If you have a disorder or any known ailments and/or are taking any medications that influence your nervous system (other than the birth control pill) you may be ineligible to participate. If you have a physical limitation impairing your ability to exercise, you have previously participated in other yoga studies with us, and you are currently practicing yoga you may also be ineligible to participate.

PROCEDURES

If you volunteer to participate in this study, you will be offered offered twice weekly free Ashtanga yoga classes for 6 weeks at the Windsor Jewish Community Centre. You will come into the lab at the University of Windsor **three** times, as described in detail below.

Preamble

Ashtanga is a vigorous yoga practice aimed at developing strength, flexibility and mental focus. The coordination of breath and movement, together with the effort and technique required to transition between poses, and to enter and maintain each pose, requires intense mental focus. This mental focus induces a meditative state that is believed to promote a calm and focussed approach to daily life. To get the benefits of Ashtanga yoga, you must practice regularly. This is why we are offering two classes per week. These practices will be physically and mentally demanding. Expect to sweat profusely. In addition, instruction in Ashtanga yoga involves adjustments that require physical contact between the teacher, or assistant, and the student. Although such physical contact is done with the utmost respect, if you are highly uncomfortable with being touched by others, training in Ashtanga yoga may not be appropriate for you.

Overview

This study and programme of training consist of 2 assessments of your autonomic nervous system, 2 surveys, and 12 yoga classes.

Before coming into the lab for your pre- and post-assessments, please:

- Do not to exercise vigorously (e.g., exercise that causes you to breath really hard and sweat heavily) for 24 hours
- Do not drink alcohol for 24 hours
- Avoid caffeine for at least 12 hours
- Avoid eating for at least 2 hours

Both the pre- and post-assessment sessions will take place at the same time of day (within 3 hours), in a quiet, temperature-controlled room. On assessment days, you will be asked to go to the washroom beforehand, as a full bladder can increase your blood pressure.

Visit 1 (approximately 1 hour):

Before the start of the study, you will meet with the researchers at the Physical Activity and Cardiovascular Research (PACR) Laboratory (Room #240, Human Kinetics Building, University of Windsor, Windsor, Ontario, Canada) where you will receive a consent form. At this time, one of the study investigators will explain all parts of the study. If you are still interested in participating in the study, you will be asked to sign the consent form and fill out a physical readiness questionnaire called a PAR-Q+. If you are still eligible to participate, you then will have your blood pressure (BP) measured in your upper arm, similar to how it is taken at a doctor's office. In brief, your BP will be measured in your upper dominant arm after 10 minutes of seated rest. Your BP will be measured 4 times, with 2 minutes of rest between measures. If you are eligible to participate, you will then practice all parts of the study with the researchers.

Visits 2 and 3 (approximately 1.5 hours each):

Prior to the first yoga class and following the last class (Week 7), you will return to the PACR lab for your pre- and post-assessment sessions.

After emptying your bladder, your resting BP will be measured after 10-minutes of seated rest in the same way as it was on your first visit. Next, you will lay down face-up on a laboratory bed, and your heart rate will be monitored using 3 sticker-electrodes that will be placed on your chest, and a breathing belt around your rib cage. After 20-minutes of rest, HR and breathing rate will be recorded over a 10-minute period.

After that, we will remove all recording equipment and you will then move to a computer terminal where you will fill out a computer-based survey. To give you privacy while you complete the survey, the researchers will wait in an isolated part of the lab that is easily accessible should you have any questions.

Yoga Classes

After you have completed Visit 2 at the lab you will be invited to the yoga classes. You will receive 12 yoga classes over 6 weeks. Bring your own mat and wear light clothing.

The yoga classes will be offered by registered Ashtanga yoga teacher Josée Jarry. In these classes, you will learn a series of increasingly challenging poses building upon each other. You will receive detailed instruction in the appropriate technique and alignment for each yoga pose and for the transition between them. The goal of this incremental practice is to build strength, flexibility and mental focus. **We ask that you attend at least 75% of the classes to progress, get the benefits of the practice and avoid injuries.** You may withdraw at any time.

Yoga Class Schedule

There will be 12 yoga classes. The yoga classes will take place every Tuesday and Thursday for the duration of the study from 5:00 to 6:15 p.m. at the Windsor Jewish Community Centre, located at 1641 Ouellette Avenue. The centre is a 20-minute direct bus ride from campus if you take the 1C bus on University Avenue. Get off at the Hanna stop. If you are driving, there is plenty of free parking.

POTENTIAL RISKS AND DISCOMFORTS

There is minimal risk of physical injury inherent to all yoga practices. These will be mitigated by the fact that classes will be taught by a Yoga Alliance (YA, www.yogaalliance.org) certified teacher with extensive experience and training.

The blood pressure measurement procedure is non-invasive but you may experience temporary numbness and/or tingling in the limb with the cuff(s) while we are taking our measurements. The sticker-electrodes used to measure your heart rate may, in rare cases, cause a skin irritation; however, this risk is minimal.

Both the testing and the yoga classes involve physical contact (e.g., placing electrodes for the physiological testing, hands on adjustments during the yoga classes). Although physical contact will be done with the utmost respect for personal boundaries, if you are highly uncomfortable with being touched, participation in the study may not be indicated for you.

Please contact one of the study investigators if you feel any adverse effects from completing any portion of the study, and/or if you have any questions or concerns. Study investigators will reinforce proper technique throughout the study. If you experience any adverse effects during any testing procedure, first line response will be provided.

POTENTIAL BENEFITS TO PARTICIPANTS AND/OR TO SOCIETY

By being involved in this study, you will get detailed instruction as well as individual adjustments and attention by a certified Ashtanga yoga teacher; thus, you may physically and psychologically benefit from the yoga classes. The free yoga classes also are a considerable benefit; this represents one and a half months of twice weekly free yoga. Normally, students are charged approximately $10–20 for drop in classes at yoga studios. Furthermore, this programme is unique in offering progressive instruction over 6 weeks to a closed group. Finally, you may or may not experience a change in the function of your nervous system.

COMPENSATION FOR PARTICIPATION

At the end of each yoga class, you will receive a ballot for entry into a draw for a 'Yoga Essentials Kit' (mat, bag, water bottle, and Ashtanga Yoga DVD). All participants will receive a Kinesiology Research memento upon their completion of the study.

CONFIDENTIALITY

Any information that is obtained in connection with this study and that can be identified with you will remain confidential. To ensure your confidentiality, following your consent, you will be assigned an identification number. Your name will not be mentioned in any publication or presentation, and you will be identified with only your identification number on all collection tools (electronic or otherwise). All paper data will be stored in the locked laboratory (PACR Lab, Room #240, Human Kinetics Building, University of Windsor) and all electronic data stored on password protected laboratory computers and back-up storage devices. The raw data from the computer-based surveys will be kept on the Qualtrics server for the duration of the study. It can only be accessed by password by the study investigators. Once the data collection is complete, the data will be downloaded in an SPSS spreadsheet and kept on the Principal Investigator's computer hard drive as well as on the lab computer's hard drive, both of which are password protected. Data will be retained for approximately 10 years, after which they will be destroyed. This is in compliance with psychology discipline guidelines of keeping data for seven years post publication. Should you report suicidal ideation in the surveys, we will contact you to offer you community resources.

PARTICIPATION AND WITHDRAWAL

After attending some yoga classes, you may realise that Ashtanga yoga is not for you. We suggest that you attend at least five classes before making this decision. However, you also are free to withdraw at any time and to withdraw your data from the analyses prior to completing nine yoga classes. You may also refuse to answer any questions you do not wish to answer and still remain in the study. The investigator may withdraw you from this research if circumstances arise which warrant doing so (i.e., four consecutive yoga classes missed). If you are a student at the University of Windsor, be advised that remaining in, or withdrawal from, the study will have no bearing whatsoever on the education that you receive in your programme at the University and will have no influence on any component of your student evaluations. In any of the cases described above, you will still receive a Kinesiology Research memento.

FEEDBACK OF THE RESULTS OF THIS STUDY TO THE PARTICIPANTS

At the completion of the study, you will receive an information letter that outlines our hypotheses. The findings of the study are expected to be available to participants in September, 2018. The results be posted on the University of Windsor's Research Ethics Board (REB) website (http://www.uwindsor.ca/reb) at the completion of the study.

SUBSEQUENT USE OF DATA

These data may be used in subsequent studies, in publications, in presentations and for promotional materials for future yoga or related studies. These data also may be combined with future data from subsequent yoga studies. However, your privacy will be upheld with the use of your unique subject identification number under all circumstances.

RIGHTS OF RESEARCH PARTICIPANTS

You may withdraw your consent at any time and discontinue participation without penalty. If you have questions regarding your rights as a research participant, contact: Research Ethics Coordinator, University of Windsor.

SIGNATURE OF RESEARCH PARTICIPANT/LEGAL REPRESENTATIVE

I understand the information provided for the study "The psychophysiological mechanisms underlying the reported effects of Ashtanga yoga: Feasibility and preliminary effectiveness study" as described herein. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

____
Name of Participant

______________________________________ ____________________
Signature of Participant Date

SIGNATURE OF INVESTIGATOR

These are the terms under which I will conduct research.

______________________________________ ____________________
Signature of Investigator Date

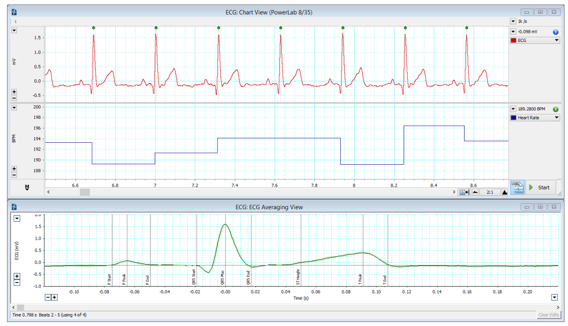
Appendix F

Resting Blood Pressure Device

Dinamap Carescape v100, Critikon, Tampa, Florida, USA

Appendix G

ECG Data Acquisition System



PowerLab ML 870/P, ADinstruments, Colorado Springs, Colorado, USA

Appendix H

Psychological Survey Battery

Beck Depression Inventory-II (BDI-II; Beck, Steer, & Brown, 1996)

Instructions: This questionnaire consists of 21 groups of statements. Please read each group of statements carefully, and then pick out the **one statement** in each group that best describes the way you have been feeling during the **past two weeks, including today.** Circle the number beside the statement you have picked. If several statements in the group seem to apply equally well, circle the highest number for that group. Be sure that you do not choose more than one statement for any group, including Item 16 (Changes in Sleeping Pattern) or Item 18 (Changes in Appetite).

1. Sadness 0 I do not feel sad. 1 I feel sad much of the time. 2 I am sad all the time. 3 I am so sad or unhappy that I can't stand it.	**12. Loss of Interest** 0 I have not lost interest in other people or activities. 1 I am less interested in other people or things than before. 2 I have lost most of my interest in other people or things. 3 It's hard to get interested in anything.
2. Pessimism 0 I am not discouraged about my future. 1 I feel more discouraged about my future than I used to be. 2 I do not expect things to work out for me. 3 I feel my future is hopeless and will only get worse.	**13. Indecisiveness** 0 I make decisions about as well as ever. 1 I find it more difficult to make decisions than usual. 2 I have much greater difficulty in making decisions than I used to. 3 I have trouble making any decisions.
3. Past Failure 0 I do not feel like a failure. 1 I have failed more than I should have. 2 As I look back, I see a lot of failures. 3 I feel I am a total failure as a person.	**14. Worthlessness** 0 I do not feel I am worthless. 1 I don't consider myself as worthwhile and useful as I used to. 2 I feel more worthless as compares to other people. 3 I feel utterly worthless.
4. Loss of Pleasure 0 I get as much pleasure as I ever did from the things I enjoy. 1 I don't enjoy things as much as I used to. 2 I get very little pleasure from the things I used to enjoy. 3 I can't get any pleasure from the things I used to enjoy.	**15. Loss of Energy** 0 I have as much energy as ever. 1 I have less energy than I used to have. 2 I don't have enough energy to do very much. 3 I don't have enough energy to do anything.
5. Guilty Feelings 0 I don't feel particularly guilty. 1 I feel guilty over many things I have done or should have done. 2 I feel quite guilty most of the time. 3 I feel guilty all of the time.	**16. Changes in Sleeping Pattern** 0 I have not experienced any change in my sleeping pattern. a I sleep somewhat more than usual. 1b I sleep somewhat less than usual. 2a I sleep a lot more than usual. 2b I sleep a lot less than usual. 3a I sleep most of the day. 3b I wake up 1-2 hours early and can't get back to sleep.
6. Punishment Feelings 0 I don't feel I am being punished. 1 I feel I may be punished. 2 I expect to be punished. 3 I feel I am being punished.	**17. Irritability** 0 I am no more irritable than usual. 1 I am more irritable than usual. 2 I am much more irritable than usual. 3 I am irritable all the time.

7. Self-Dislike 0 I feel the same about myself as ever. 1 I have lost confidence in myself. 2 I am disappointed in myself. 3 I dislike myself.	**18. Changes in Appetite** 0 I have not experienced any change in my appetite. . a My appetite is somewhat less than usual. b1 My appetite is somewhat greater than usual. . a My appetite is much less than before. 2b My appetite is much greater than usual. . 3a I have no appetite at all. 3b I crave food all the time.
8. Self-Criticalness 0 I don't criticize or blame myself more than usual. 1 I am more critical of myself than I used to be. 2 I criticize myself for all my faults. 3 I blame myself for everything bad that happens.	**19. Concentration Difficulty** 0 I can concentrate as well as ever. 1 I can't concentrate as well as usual. 2 It's hard to keep my mind on anything for very long. 3 I find I can't concentrate on anything.
9. Suicidal Thought or Wishes 0 I don't have any thoughts of killing myself. 1 I have thoughts of killing myself, but I would not carry them out. 2 I would like to kill myself. 3 I would kill myself if I had the chance.	**20. Tiredness or Fatigue** 0 I am no more tired or fatigued than usual. 1 I get more tired or fatigued more easily than usual. 2 I am too tired or fatigued to do a lot of the things I used to do. 3 I am too tired or fatigued to do most of the things I used to do.
10. Crying 0 I don't cry any more than I used to. 1 I cry more than I used to. 2 I cry over every little thing. 3 I feel like crying, but I can't.	**21. Loss of Interest in Sex** 0 I have not noticed any recent change in my interest in sex. 1 I am less interested in sex than I used to be. 2 I am much less interested in sex now. 3 I have lost interest in sex completely.
11. Agitation 0 I am no more restless or wound up than usual. 1 I feel more restless or wound up than usual. 2 I am so restless or agitated that it's hard to stay still. 3 I am so restless or agitated that I have to keep moving or doing something.	

Positive Negative Affect Scale (PANAS; Watson et al., 1988)

This scale consists of a number of words that describe different feelings and emotions. Read each item and then mark the appropriate answer in the space next to that word. Indicate to what extent you feel this way *right now*, that is, *at the present moment*. Use the following scale to record your answers.

1	2	3	4	5
very slightly or not at all	a little	moderately	quite a bit	extremely

interested	inspired	afraid
distressed	nervous	enthusiastic
excited	determined	proud
upset	attentive	irritable
strong	jittery	alert
guilty	hostile	scared
ashamed	active	

State-Trait Anxiety Inventory-Y (STAI -Y; Spielberger, Gorsuch, Lushene & Jacobs, 1983)

STATE: A number of statements which people have used to describe themselves are given below. Read each statement and then circle the appropriate number to the right of the statement to indicate how you feel ***right now,*** that is, at this ***moment***. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

	Not at all	Somewhat	Moderately so	Very much so
1. I feel calm	**1**	**2**	**3**	**4**
2. I feel secure	**1**	**2**	**3**	**4**
3. I am tense	**1**	**2**	**3**	**4**
4. I feel strained	**1**	**2**	**3**	**4**
5. I feel at ease	**1**	**2**	**3**	**4**
6. I feel upset	**1**	**2**	**3**	**4**
7. I am presently worrying over possible misfortunes	**1**	**2**	**3**	**4**
8. I feel satisfied	**1**	**2**	**3**	**4**
9. I feel frightened	**1**	**2**	**3**	**4**
10. I feel comfortable	**1**	**2**	**3**	**4**
11. I feel self-confident	**1**	**2**	**3**	**4**
12. I feel nervous	**1**	**2**	**3**	**4**
13. I am jittery	**1**	**2**	**3**	**4**
14. I feel indecisive	**1**	**2**	**3**	**4**
15. I am relaxed	**1**	**2**	**3**	**4**
16. I feel content	**1**	**2**	**3**	**4**
17. I am worried	**1**	**2**	**3**	**4**
18. I feel confused	**1**	**2**	**3**	**4**
19. I feel steady	**1**	**2**	**3**	**4**
20. I feel pleasant	**1**	**2**	**3**	**4**

TRAIT: A number of statements which people have used to describe themselves are given below. Read each statement and then circle the appropriate number to the right of the statement to indicate how you feel ***generally feel***. There are no right or wrong answers. Don't spend too much time on any statement but give the answer which seems to describe how you ***generally feel.***

	Almost Never	**Sometimes**	**Often**	**Almost Always**
21. I feel pleasant	1	2	3	4

22. I feel nervous and restless	1	2	3	4
23. I am satisfied with myself	1	2	3	4
24. I wish I could be as happy as others seem to be	1	2	3	4
25. I feel like a failure	1	2	3	4
26. I feel rested	1	2	3	4
27. I am 'calm, cool, and collected.'	1	2	3	4
28. I feel that difficulties are piling up so that I cannot overcome them	1	2	3	4
29. I worry too much over something that really doesn't matter	1	2	3	4
30. I am happy	1	2	3	4
31. I have disturbing thoughts	1	2	3	4
32. I lack self-confidence	1	2	3	4
33. I feel secure	1	2	3	4
34. I make decisions easily	1	2	3	4
35. I feel inadequate	1	2	3	4
36. I am content	1	2	3	4
37. Some unimportant thought runs through my mind and bothers me	1	2	3	4
38. I take disappointments so keenly that I can't put them out of my mind	1	2	3	4
39. I am a steady person	1	2	3	4
40. I get in a state of tension or turmoil as I think over my recent concerns and interests	1	2	3	4

Rosenberg Self-esteem Scale (RSES; Rosenberg, 1965)

Instructions: Below is a list of statements dealing with your general feelings about yourself. If you strongly agree, circle **SA**. If you agree with the statement, circle **A**. If you disagree, circle **D**. If you strongly disagree, circle **SD**.

1.	On the whole, I am satisfied with myself.	SA	A	D	SD
2.	At times, I think I am no good at all.	SA	A	D	SD
3.	I feel that I have a number of good qualities.	SA	A	D	SD
4.	I am able to do things as well as most other people.	SA	A	D	SD

5.	I feel I do not have much to be proud of.	SA	A	D	SD
6.	I certainly feel useless at times.	SA	A	D	SD
7.	I feel that I'm a person of worth, at least on an equal plane with others.	SA	A	D	SD
8.	I wish I could have more respect for myself.	SA	A	D	SD
9.	All in all, I am inclined to feel that I am a failure.	SA	A	D	SD
10.	I take a positive attitude toward myself.	SA	A	D	SD

State Self-Esteem Scale (SSES; Heatherton & Polivy, 1991)

This is a questionnaire designed to measure what you are thinking AT THIS MOMENT. There is, of course, no right answer for any statement. The best answer is what you feel is true of yourself at this moment. Be sure to answer all of the items, even if you are not certain of the best answer. Again, answer these questions as they are true for you RIGHT NOW.

1 = not at all   2 = a little bit   3 = somewhat   4 = very much   5 = extremely

1 I feel confident about my abilities. . . . . __________
2 I am worried about whether I am regarded as a success or failure. . . . . __________
3 I feel satisfied with the way my body looks right now. . . . . __________
4 I feel frustrated or rattled about my performance. . . . . __________
5 I feel that I am having trouble understanding things that I read. . . . . __________
6 I feel that others respect and admire me. . . . . __________
7 I am dissatisfied with my weight. . . . . __________
8 I feel self-conscious. . . . . __________
9 I feel as smart as others. . . . . __________
10 I feel displeased with myself. . . . . __________
11 I feel good about myself. . . . . __________
12 I am pleased with my appearance right now. . . . . __________
13 I am worried about what other people think of me. __________
14 I feel confident that I understand things. . . . . __________
15 I feel inferior to others at this moment. . . . . __________
16 I feel unattractive. . . . . __________
17 I feel concerned about the impression I am making. . . . . __________
18 I feel that I have less scholastic ability right now than others. . . . . __________
19 I feel like I'm not doing well. . . . . __________
20 I am worried about looking foolish. . . . . __________

Inventory of Interpersonal Problems-32 (IIP-32; Horowitz, 1988)

People have reported having the following problems in relating to other people. Please read the list below, and for each item, consider whether it has been a problem for you with respect to **any** significant person in your life. Then circle the number that describes how distressing that problem has been.

0 - Not at all
1 - A little bit
2 - Moderately
3 - Quite a bit
4 - Extremely

The following are things you find hard to do with other people.

It is hard for me to:

1. Say "no" to other people.	0	1	2	3	4
2. Join in on groups.	0	1	2	3	4
3. Keep things private from other people.	0	1	2	3	4
4. Tell a person to stop bothering me.	0	1	2	3	4
5. Introduce myself to new people.	0	1	2	3	4
6. Confront people with problems that come up.	0	1	2	3	4
7. Be assertive with another person.	0	1	2	3	4
8. Let other people know when I am angry.	0	1	2	3	4
9. Socialize with other people.	0	1	2	3	4
10. Show affection to people.	0	1	2	3	4
11. Get along with people.	0	1	2	3	4
12. Be firm when I need to be.	0	1	2	3	4
13. Experience a feeling of love for another person.	0	1	2	3	4
14. Be supportive of another person's goals in life.	0	1	2	3	4
15. Feel close to other people.	0	1	2	3	4
16. Really care about other people's problems.	0	1	2	3	4
17. Put somebody else's needs before my own.	0	1	2	3	4
18. Feel good about another person's happiness.	0	1	2	3	4
19. Ask other people to get together socially with me.	0	1	2	3	4
20. Be assertive without worrying about hurting the other person's feelings.	0	1	2	3	4

The following are things that you do too much.

21. I open up to people too much.	0	1	2	3	4
22. I am too aggressive toward other people.	0	1	2	3	4
23. I try to please other people too much.	0	1	2	3	4
24. I want to be noticed too much.	0	1	2	3	4
25. I try to control other people too much.	0	1	2	3	4
26. I put other people's needs before my own too much.	0	1	2	3	4
27. I am overly generous to other people.	0	1	2	3	4
28. I manipulate other people too much to get what I want.	0	1	2	3	4
29. I tell personal things to other people too much.	0	1	2	3	4
30. I argue with other people too much.	0	1	2	3	4
31. I let other people take advantage of me too much.	0	1	2	3	4
32. I am affected by another person's misery too much.	0	1	2	3	4

Five Facet Mindfulness Questionnaire (FFMQ; Baer, Smith, Hopkins, Krietemeyer, & Toney, 2006)

Please rate each of the following statements with the number that best describes *your own opinion* of what is *generally true for you*.

Remember, your responses are confidential, so please be completely honest and answer all items.

1	2	3	4	5
Never or Very Rarely True	**Not Often True**	**Sometimes True, Sometimes Not**	**Often True**	**Very Often or Always True**

________	1. When I'm walking, I deliberately notice the sensations of my body moving.
________	2. I'm good at finding the words to describe my feelings.
________	3. I criticize myself for having irrational or inappropriate emotions.
________	4. I perceive my feelings and emotions without having to react to them.
________	5. When I do things, my mind wanders off and I'm easily distracted.
________	6. When I take a shower or bath, I stay alert to the sensations of water on my body.
________	7. I can easily put my beliefs, opinions, and expectations into words
________	8. I don't pay attention to what I'm doing because I'm daydreaming, worrying, or otherwise distracted.
________	9. I watch my feelings without getting lost in them.
________	10. I tell myself that I shouldn't be feeling the way I'm feeling.
________	11. I notice how foods and drinks affect my thoughts, bodily sensations, and emotions.
________	12. It's hard for me to find the words to describe what I'm thinking.
________	13. I am easily distracted.
________	14. I believe some of my thoughts are abnormal or bad and I shouldn't think that way.
________	15. I pay attention to physical experiences, such as the wind in my hair or sun on my face
________	16. I have trouble thinking of the right words to express how I feel about things. r
________	17. I make judgments about whether my thoughts are good or bad.
________	18. I find it difficult to stay focused on what's happening in the present moment.
________	19. When I have distressing thoughts or images, I "step back" and am aware of the thought or image without getting taken over by it.
________	20. I pay attention to sounds, such as clocks ticking, birds chirping, or cars passing.
________	21. In difficult situations, I can pause without immediately reacting.
________	22. When I feel something in my body, it's hard for me to find the right words to describe it.
________	23. It seems I am "running on automatic" without much awareness of what I'm doing.
________	24. When I have distressing thoughts or images, I feel calm soon after.
________	25. I tell myself I shouldn't be thinking the way I'm thinking.
________	26. I notice the smells and aromas of things.

__________ 27. Even when I'm feeling terribly upset, I can find a way to put it into words.

__________ 28. I rush through activities without being really attentive to them.

__________ 29. When I have distressing thoughts or images I am able just to notice them without reacting

__________ 30. I think some of my emotions are bad or inappropriate and I shouldn't feel them.

__________ 31. I notice visual elements in art or nature, such as colors, shapes, textures, or patterns of light and shadow.

__________ 32. My natural tendency is to put my experiences into words.

__________ 33. When I have distressing thoughts or images, I just notice them and let them go.

__________ 34. I do jobs or tasks automatically without being aware of what I'm doing.

__________ 35. When I have distressing thoughts or images, I judge myself as good or bad, depending what the thought/image is about.

__________ 36. I pay attention to how my emotions affect my thoughts and behaviour.

__________ 37. I can usually describe how I feel at the moment in considerable detail.

__________ 38. I find myself doing things without paying attention.

__________ 39. I disapprove of myself when I have illogical ideas.

Perceived Stress Scale (PSS; Cohen et al., 1983)

The questions in this scale ask you about your feelings and thoughts during the last month. In each case, you will be asked to indicate by circling *how often* you felt or thought a certain way.

0 = Never 1 = Almost Never 2 = Sometimes 3 = Fairly Often 4 = Very Often

1. In the last month, how often have you been upset because of something that happened unexpectedly?......................................0 1 2 3 4

2. In the last month, how often have you felt that you were unable to control the important things in your life? 0 1 2 3 4

3. In the last month, how often have you felt nervous and "stressed"? 0 1 2 3 4

4. In the last month, how often have you felt confident about your ability to handle your personal problems? 0 1 2 3 4

5. In the last month, how often have you felt that things were going your way?... 0 1 2 3 4

6. In the last month, how often have you found that you could not cope with all the things that you had to do? 0 1 2 3 4

7. In the last month, how often have you been able to control irritations in your life?... 0 1 2 3 4

8. In the last month, how often have you felt that you were on top of things?.. 0 1 2 3 4

9. In the last month, how often have you been angered because of things that were outside of your control?.................................... 0 1 2 3 4

10. In the last month, how often have you felt difficulties

were piling up so high that you could not overcome them? 0 1 2 3 4

Demographic Questionnaire

Age: _______ Sex: _______

Marital status:
Married/common law___ Divorced/separated___ Single___ Widowed ___

Number of children: 0 ___ 1 ___ 2 ___ 3 ___ 4 ___ more than 4 ___

What is your ethnic background?

Caucasian	___	South Asian	___	Hispanic	___
African-Canadian	___	European	___	Native-Canadian	___
East Asian	___	Other (please specify): _________________________			

School enrolment:
Full time student ___ Part time student ___

Years in University:
First year ___ Third year___ More than 4 years ___
Second year___ Fourth year___

Including your current psychology course, how many psychology courses have you taken so far? ________

What is/are your major(s)? ____

What is/are your minor(s)? ____

If currently employed, your occupation is:
Full time ___ Clerical ___ Labourer ___
Part time ___ Professional___ Self-employed___
Owner/manager___ Unemployed___
Other: ____________________________

Appendix I

Ashtanga Yoga Intervention Class Outline

Total of 12 classes over 6 weeks. Classes took place twice per week were structured as follows:

Class 1 – March 20, 2018

Intro to Ashtanga yoga
- The goal of yoga: meditative state
- Why hard physical exercise?
- The breath count
- Bandhas
- Drsti
- The importance of correct alignment and technique
- The Om
- The chant

Intro to Sun Salutation

• Suryanamaskara A	Sun Salutation A
• Suryanamaskara B	Sun Salutation B

Finishing sequence

• Urdhva dhanurasana (or bridge)	Upward bow pose
• Pascimattanasana	West stretching pose

Closing sequence

• Salamba sarvangasana	All limbs supported pose
• Halasana	Plough pose
• Baddha Padmasana	Bound Lotus pose
• Yoga Mudra	Yoga gesture
• Padmasana	Lotus pose
• Utpluthih	Sprung up

Take rest

Class 2 – March 22, 2018

2–3 minute discussion about ahimsa	Nonviolence

Suryanamaskara A – 5 times	Sun Salutation A
Suryanamaskara B – 5 times	Sun Salutation B

Fundamental Asanas - partial:

• Padangusthasana	Hands to foot thumb pose
• Pada hastasana	Feet on hand pose

Finishing sequence

• Urdhva dhanurasana (or bridge)	Upward bow pose
• Pascimattanasana	West stretching pose

Closing sequence

• Salamba sarvangasana	All limbs supported pose
• Halasana	Plough pose

- Karna pidasana — Ear pressure pose
- Baddha Padmasana — Bound Lotus pose
- Yoga Mudra — Yoga gesture
- Padmasana — Lotus pose
- Utpluthih — Sprung up

Take rest

Class 3 – March 27, 2018

2–3 minute discussion about satya	Truthfulness
Suryanamaskara A – 5 times	Sun Salutation A
Suryanamaskara B – 5 times	Sun Salutation B

Fundamental Asanas - partial:

- Padangusthasana — Hands to foot thumb pose
- Pada hastasana — Feet on hand pose
- Utthita Trikonasana A — Extended Triangle
- Utthita Trikonasana B — Extended Reversed Triangle

Primary series

- Janusirsasana A — Knee head pose
- Maricasana A — Marici pose A

Finishing sequence

- Urdhva dhanurasana (or bridge) — Upward bow pose
- Pascimattanasana — West stretching pose

Closing sequence

- Salamba sarvangasana — All limbs supported pose
- Halasana — Plough pose
- Karna pidasana — Ear pressure pose
- Urdhva Padmasana — Upward Lotus
- Pindhasana — Embryo pose
- Matsyasana — Fish pose
- Uttana Padasana — Extended foot pose
- Sirsasana - preparation — Head pose
- Baddha Padmasana — Bound Lotus pose
- Yoga Mudra — Yoga gesture
- Padmasana — Lotus pose
- Utpluthih — Sprung up

Take rest

Class 4 – March 29, 2018

2–3 minute discussion about asteya	Non-stealing

Om
Chant

Suryanamaskara A – 5 times	Sun Salutation A
Suryanamaskara B – 5 times	Sun Salutation B

Fundamental Asanas - partial:

• Padangusthasana	Hands to foot thumb pose
• Pada hastasana	Feet on hand pose
• Utthita Trikonasana A	Extended Triangle
• Utthita Trikonasana B	Extended Reversed Triangle
• Utthita Parsvakonasana A	Extended Side Angle Intense A
• Utthita Parsvakonasana B	Extended Side Angle Intense B

Primary series

• Janusirsasana A	Knee head pose
• Maricasana A	Marici pose A
• Maricasana C	Marici pose C
• Navasana	Boat pose

Finishing sequence
Closing sequence
Take rest

Class 5 – April 3, 2018

2–3 minute discussion about brahmacharya	Sexual continence

Om
Chant

Suryanamaskara A – 5 times	Sun Salutation A
Suryanamaskara B – 5 times	Sun Salutation B

Fundamental Asanas - complete:

• Padangusthasana	Hands to foot thumb pose
• Pada hastasana	Feet on hand pose
• Utthita Trikonasana A	Extended Triangle
• Utthita Trikonasana B	Extended Reversed Triangle
• Utthita Parsvakonasana A	Extended Side Angle Intense A
• Utthita Parsvakonasana B	Extended Side Angle Intense B
• Prasarita Padottanasana A	Wide foot stretching pose A
• Prasarita Padottanasana B	Wide foot stretching pose B
• Parsvottanasana	Stretching pose

Primary series

• Janusirsasana A	Knee head pose
• Maricasana A	Marici pose A
• Maricasana C	Marici pose C
• Navasana	Boat pose

Finishing sequence
Closing sequence
Take rest

Class 6 – April 5, 2018

2–3 minute discussion about aparigraha	Non-atachament

Om
Chant

Suryanamaskara A – 5 times	Sun Salutation A
Suryanamaskara B – 5 times	Sun Salutation B

Fundamental Asanas – complete:

• Padangusthasana	Hands to foot thumb pose
• Pada hastasana	Feet on hand pose
• Utthita Trikonasana A	Extended Triangle
• Utthita Trikonasana B	Extended Reversed Triangle
• Utthita Parsvakonasana A	Extended Side Angle Intense A
• Utthita Parsvakonasana B	Extended Side Angle Intense B
• Prasarita Padottanasana A	Wide foot stretching pose A
• Prasarita Padottanasana B	Wide foot stretching pose B
• Prasarita Padottanasana C	Wide foot stretching pose C
• Prasarita Padottanasana D	Wide foot stretching pose D
• Parsvottanasana	Stretching pose

Primary series

• Utthita Hasta Padangustasana A, B, C	Extended hand to foot thumb pose
• Ardha Baddha Padmottanasana	Half bound lotus
• Utkatasana	Uneven pose
• Virabhadrasana	Warrior pose
• Dandasana	Staph pose
• Paschimattasana A, C	West stretching pose
• Purvattanasana	East stretching pose
• Janusirsasana A	Knee head pose
• Janusirsasana B	Knee head pose
• Maricasana A	Marici pose A
• Maricasana B	Marici pose B
• Maricasana C	Marici pose C
• Navasana	Boat pose

Finishing sequence
Closing sequence
Take rest

Class 7 – April 10, 2018

2–3 minute discussion about saucha	Cleanliness of mind and body

Om
Chant

Suryanamaskara A – 5 times	Sun Salutation A
Suryanamaskara B – 5 times	Sun Salutation B

Fundamental Asanas – complete:

• Padangusthasana	Hands to foot thumb pose
• Pada hastasana	Feet on hand pose
• Utthita Trikonasana A	Extended Triangle
• Utthita Trikonasana B	Extended Reversed Triangle
• Utthita Parsvakonasana A	Extended Side Angle Intense A
• Utthita Parsvakonasana B	Extended Side Angle Intense B
• Prasarita Padottanasana A	Wide foot stretching pose A
• Prasarita Padottanasana B	Wide foot stretching pose B
• Prasarita Padottanasana C	Wide foot stretching pose C
• Prasarita Padottanasana D	Wide foot stretching pose D
• Parsvottanasana	Stretching pose

Primary series

• Utthita Hasta Padangustasana A, B, C	Extended hand to foot thumb pose
• Ardha Baddha Padmottanasana	Half bound lotus
• Utkatasana	Uneven pose
• Virabhadrasana	Warrior pose
• Dandasana	Staph pose
• Paschimattasana A, C	West stretching pose
• Purvattanasana	East stretching pose
• Janusirsasana A	Knee head pose
• Janusirsasana B	Knee head pose
• Maricasana A	Marici pose A
• Maricasana B	Marici pose B
• Maricasana C	Marici pose C
• Navasana	Boat pose

Finishing sequence
Closing sequence
Take rest

Class 8 – April 12, 2018

Om
Chant

Suryanamaskara A – 5 times	Sun Salutation A
Suryanamaskara B – 3 times	Sun Salutation B

Fundamental Asanas

Primary Series

• Utthita Hasta Padangustasana A, B, C	Extended hand to foot thumb pose
• Ardha Baddha Padmottanasana	Half bound lotus
• Utkatasana	Uneven pose
• Virabhadrasana A & B	Warrior pose
• Dandasana	Staph pose
• Paschimattanasana A, C	West stretching pose
• Purvattanasana	East stretching pose
• Ardha Baddha Padma paschimattanasana	Half Bound Lotus
• Tiryangmukha ekapada paschimattanasana	One foot folded back West Stretching pose
• Janusirsasana A	Knee head pose A
• Janusirsasana B	Knee head pose B
• Janusirsasana C	Knee head pose C
• Maricasana A	Marici pose A
• Maricasana B	Marici pose B
• Maricasana C	Marici pose C
• Maricasana D	Marici pose D
• Navasana	Boat pose
• Bhujapidasana -- preparation	Arm pressure pose

Finishing sequence
Closing sequence
Take rest

The following 4 classes were the same as Class 8.

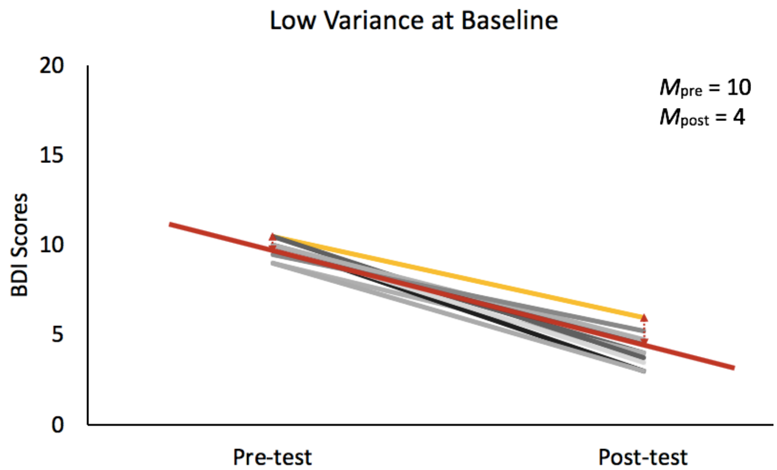
Appendix J

Difference Scores versus Residualized Change Scores

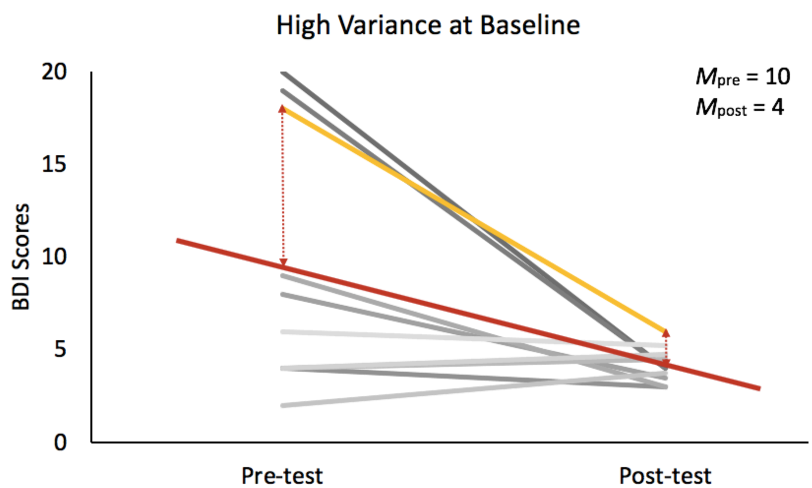
Consider the following two hypothetical scenarios for a comparison between the difference score approach and the residualized change score approach. In Scenario 1 (Graph A), baseline depression scores have low variance (i.e., minimal individual differences between participants) with a mean of 10, and at the conclusion of the intervention, post-test scores show a mean of 4. Here, the difference score method (i.e., post-test – pre-test) would conclude that depression scores showed a 6-point decrease post-intervention. Upon closer inspection of Graph A it appears that, on average, participants experienced the same amount of change from pre-test to post-test, so the residuals are close to zero. In Scenario 2 (Graph B), baseline depression scores have high variance. Given that the grand means are identical in both scenarios, the difference score method again would conclude that depression scores showed a 6-point decrease post-intervention. Examination of Graph B, however, reveals that some depression scores showed up to 16-point decreases (larger residual), whereas other scores did not change or slightly increased (smaller residual). Therefore, although the difference score method yields the same outcome in both scenarios, it inflates or deflates the magnitude of individual changes and thus skews interpretation of results. See Appendix L for a profound example of this phenomenon occurring in the present investigation.

In sum, calculating standardized residuals allows for closer examination of the magnitude of change that may be accounted for by the intervention such that residuals close to zero represent little to no change. In other words, residualized change scores provide an estimate of the change that is *left over* after controlling for individual differences at baseline. This allows the researcher to more precisely conclude that the left-over (residual) change is, at least in part, due to the intervention rather than random error.

Note that the graphs displayed below are visual representations of residualized change scores versus change scores (Graphs A and B). The red line represents the change (slope) in the grand mean from pre-test to post-test. The yellow line represents one participant's change over the course of the hypothetical intervention. The red arrows represent residuals for one participant in the hypothetical intervention. This demonstrates the superiority of the residualized change score method such that it provides a more meaningful estimate of the magnitude of change following the intervention than the change score approach. See Appendix L for visual representations of correlations of residualized change scores using data from the present investigation.



A. Change score method.



B. Residualized change score method.

Appendix K

Intercorrelations Between All Variables at Pre-test and Post-Test

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	20
1. BDI		.48	−.55	.11	.29	−.24	.12	−.19	.51	.46	.07	.21	.46	.35	.31	.36	.47	.28	.55
2. PANAS-N	.40		−.12	−.13	−.19	.12	−.32	.10	.46	.16	.31	.23	.03	.34	.40	.45	.38	.35	.45
3. PANAS-P	−.37	.11		−.12	−.43	.29	−.28	.05	−.29	−.25	.05	.04	−.29	−.48	−.29	−.25	−.07	.15	−.48
4. STAI-S	.54	.45	−.53		.85	−.63	.73	−.26	.09	.08	.33	.33	.29	−.04	−.07	−.20	−.23	−.17	.12
5. STAI-T	.48	.30	−.68	.69		−.82	.88	−.21	.20	.22	.18	.24	.37	.17	−.01	−.08	−.01	−.29	.15
6. SSES	−.43	−.29	.65	−.64	−.92		−.82	−.05	−.41	−.39	−.32	−.30	−.35	−.30	−.10	−.12	−.25	.21	−.21
7. RSES	.59	.36	−.66	.73	.81	−.77		−.12	.02	.10	.17	.12	.22	−.01	−.20	−.21	−.04	−.27	.01
8. PSS	.51	.21	−.80	.66	.71	−.71	.72		−.04	−.16	.01	−.08	−.21	.08	.03	−.09	.13	.03	−.15
9. IIP-Total	.39	.10	−.52	.34	.68	−.55	.53	.52		.63	.64	.65	.66	.73	.68	.58	.54	.20	.50
10. OC	.12	−.18	−.21	−.03	.35	−.20	.15	.12	.58		.39	.42	.46	.29	.14	.24	.52	−.06	.48
11. SC	.43	.00	−.49	.31	.49	−.42	.36	.38	.58	.62		.87	.63	.12	.13	−.03	.12	.13	.38
12. CD	.18	−.28	−.47	.06	.38	−.24	.34	.25	.67	.53	.71		.72	.10	.08	−.03	.14	.19	.23
13. SI	.50	−.17	−.62	.21	.53	−.49	.52	.48	.66	.29	.64	.74		.30	.23	−.02	.10	.00	.39
14. NA	.16	−.04	−.56	.32	.55	−.44	.48	.39	.80	.30	.25	.48	.52		.89	.66	.34	−.04	.29
15. OA	.41	.37	−.31	.47	.49	−.42	.44	.48	.67	−.04	.14	.17	.33	.58		.73	.21	.10	.22
16. SS	.15	.48	.00	.36	.36	−.29	.38	.24	.50	.02	−.20	−.06	−.13	.49	.65		.41	.40	.23
17. IN	.05	.16	−.01	−.02	.27	−.23	−.03	.25	.54	.46	.09	.00	.03	.29	.28	.43		.23	.40
18. FFMQ-O	.18	.15	.43	−.09	−.08	.12	−.06	−.31	−.14	−.19	−.35	−.30	−.15	−.14	−.02	.20	.10		.13
20. FFMQ-AA	.57	.19	−.45	.48	.55	−.52	.58	.53	.42	.20	.18	−.01	.32	.35	.40	.35	.24	.00	

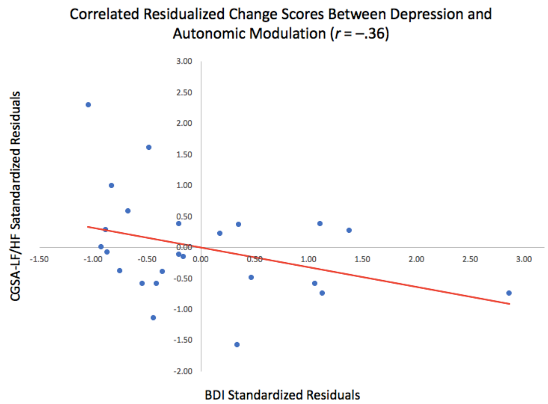
Note. Top half of the diagonal = correlations between variables at pre-test; bottom half of the diagonal = correlations between variables at post-test. BDI = Beck Depression Inventory; PANAS = Positive-Negative Affect Schedule; STAI = State-Trait Anxiety Inventory; SSES = State Self-Esteem Scale; RSES = Rosenberg Self-Esteem Scale; PSS = Perceived Stress Scale; IIP = Inventory of Interpersonal Problems; OC = overly controlling; SC = self-centered; CD = cold/distant; SI = socially inhibited; NA = non-assertive; OA = overly accommodating; SS = self-sacrificing; IN = intrusive/needy; FFMQ = Five Facet Mindfulness Questionnaire; O = observing; AA = acting with awareness.

Variable	1	2	3	4	5	6	7	8	9	10	11
1. SBP		.64	.22	.15	–.01	.25	–.01	.26	.25	–.20	.38
2. DBP	.65		.50	–.26	–.30	–.12	–.27	.06	–.07	–.46	.28
3. HR	.41	.67		–.62	–.55	–.42	.45	–.08	–.25	–.55	.06
4. SDNN	–.10	–.21	–.36		.78	.84	.73	.24	.53	.56	.23
5. RMSSD	–.35	–.42	–.45	.82		.69	.96	–.27	.37	.82	–.14
6. FFT-LF	–.04	–.15	–.21	.73	.51		.64	.34	.72	.45	.41
7. FFT-HF	–.32	–.41	–.38	.87	.90	.58		–.33	.29	.80	–.20
8. FFT-LF/HF	.41	.25	.19	–.12	–.44	.27	–.42		.36	–.32	.78
9. CGSA-LF	.13	–.09	.13	.06	.07	.25	.21	–.07		.40	.61
10. CGSA-HF	.10	–.11	–.16	.67	.60	.40	.71	–.31	.44		–.19
11. CGSA-LF/HF	.38	.17	.25	–.19	–.32	–.13	–.20	.40	.29	–.26	

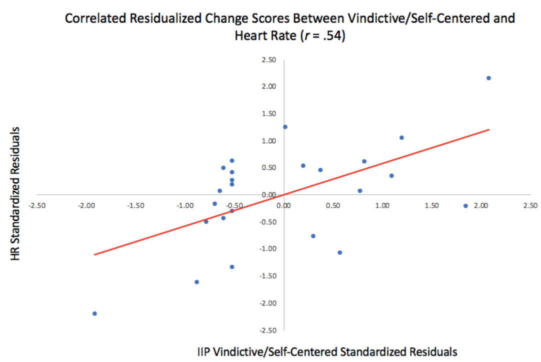
Note. Top half of the diagonal = correlations between variables at pre-test; bottom half of the diagonal = correlations between variables at post-test. SBP = systolic blood pressure; DBP = diastolic blood pressure; HR = heart rate; SDNN = standard deviation of R-R intervals; RMSSD = root mean square of R-R interval differences; FFT = fast Fourier transformation; CGSA = coarse-graining spectral analysis; LF = low frequency; HF = high frequency.

Appendix L

Scatterplot of Residualized Change Scores Using Data from the Present Study



Negatively correlated residualized change scores between BDI and CGSA-HF/LF. On average, as parasympathetic predominance increases, depression decreases.



Positively correlated residualized change scores between IIP-SC and HR. On average, as heart rate decreases, feelings of being vindictive or self-centered decrease.

Null correlations between RSES and FFT-LF/HF. On average there was no relationship between trait self-esteem and autonomic modulation.

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